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A

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ON THE

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OF

NAVAL GUNNERY.

BY

WILLIAM N. JEFFERS, JUN.,

PASSED MIDSHIPMAN, U. S. NAVY.

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PREFACE.

WITHIN a few years the subject of Naval Gunnery has attracted the notice of Naval Officers, yet it has not received from them a degree of attention commensurate with its importance.

Prominent among the causes which have produced the ignorance or want of interest which has been displayed in relation to this, the most important part of our profession, is a want of the necessary treatises to serve as a basis upon which to rest a standard, with which to compare our individual experience. A fallacious definition of the term experience has led many into the grossest errors; forgetting that "experience is not the experience of one man, or of one set of men, but of all mankind in all ages, recorded in books and registered by tradition," we are too apt, upon a very limited experience of our own, without resorting to a strict analysis, to applaud the worst, or condemn the best of systems.

Although conscious of the difficulties attending his undertaking from the lack of some of the necessary materials, the author has been induced to attempt to supply the vacuum with a Treatise in three Parts.

Part I.—the present volume—contains the Theory and Practice of Gunnery, entirely freed from mathematical formulæ, based upon the admirable work of Thiroux.[1] The text of that work has, however, furnished but a small proportion of the matter, for the author has diligently collated the most reliable authorities. He has also endeavored to render his work as concise as possible while offering a rational explanation of the causes producing the various phenomena discussed. The desire of making each chapter independent of the others has, however, in several instances rendered a repetition of the same reasoning necessary.

The authorities cited are generally foreign authors; for although extensive series of experiments have been made in this country at various times within the last fifteen years, for the determination of several important points in the practice of naval gunnery, yet it is to be inferred that no facts of importance have been elicited, since no results have been published for the instruction of the junior grades in the naval service. We have been left to pick up whatever information chance has thrown in our way, consequently our knowledge

---

[1] Instruction d'Artillerie.

has been confined to those scraps of information published by foreign governments, almost useless to ourselves on account of the difference of our system. At present, vigorous efforts are being made to establish the armament of our ships upon such a basis as shall insure the maximum of effect;—it rests with individual officers to render its employment effective.

Part II. will contain the mathematical discussions and developments of the theories upon which the practice is founded, and the formulæ for deducing all the circumstances of the motions of projectiles.

Part III. will treat of the fabrication of cannon, and the manufacture of gunpowder, projectiles, and military fire-works.

These last two volumes being entirely distinct from the first, and not necessarily connected with it, the period of their publication will depend on the encouragement this Essay may receive.

With this preface, the author leaves the result of his labors in the hands of his brethren of the service, trusting to their favorable reception of a work prepared under many disadvantages.

U. S. Naval Academy, Annapolis,
December 1849.

CONTENTS.

CHAPTER I.

DEFINITIONS AND INTRODUCTORY REMARKS.

Introductory remarks, Art. 1—4. Matter, 5. Force, 6. Action and reaction, 7. Velocity, 8. Mass, 9. Momentum, 10. Impact of bodies, 11. General properties of bodies, 12—14. Mobility, 15. Inertia, 16. Gravity, 17. Weight, 18. Density, 19. Uniform motion, 22. Variable motion, 23. Motion of projectiles, 24. Law of atmospheric resistance, 25—28. Definitions in gunnery, 29. 9

CHAPTER II.

OF ARTILLERY IN GENERAL.

Classification of cannon, Art. 30. Figure, 31. Ratio of weight to that of the projectile, 32. Recoil, 33. Measure of recoil, 34. Nomenclature, 35. Windage, 36. Chambers, their figures and properties, 37—41. Influence of the chamber, 42, 43. Durability of cannon, 44. Thickness of metal, 45, 46. Influence of external figure, 47. Material of which guns are composed, 48—51. Trunnions, their position and use, 52—54. Preponderance, 55. The vent, 56, 57. Length of guns, 58. Fabrication of cannon, 59. Proof, 60. The injuries experienced by guns in service, 61, 62. Spiking cannon and rendering them unserviceable, 63. 24

CHAPTER III.

OF GUN CARRIAGES.

Conditions to be fulfilled in service, Art. 64, 65. Methods of restraining recoil, 66—71. Resumé of conditions, 72. Principles of construction,

73, 74. Iron carriages, 75. Variations in the form of carriages, 76. Common service carriage, 77. Ward's carriage, 78. Marsilly carriage, 79. Columbiad carriage, 81. Hardy carriage, 82. *Pointing in elevation*—The common bed and quoin, 83. Elevating screw, 84. Screw quoin, 85. Chocking quoin, 86. 42

CHAPTER IV.

OF GUNPOWDER.

Ingredients, Art. 87. Proportions of the ingredients, 88—92. Inflammation of gunpowder, 93. Temperature of inflammation, 94. Period of the invention of gunpowder, 95. Explanation of its action, 96. Useful effect produced, 97. Qualities requisite, 98. MANUFACTURE OF GUNPOWDER, 99—107. COMBUSTION OF GUNPOWDER—Preliminary ideas, 108—120. Of the purity of the ingredients, 121. Of their proportions, 122. Of the mode of incorporation, 123. Of the dryness of the powder, 124. Of the ratio of the charge, 125. Of the resistance to be overcome, 126. Of the extent and form of the place where combustion takes place, 127. Of the windage and diameter of the vent, 128. Of the placè where fire is communicated to the charge, 129—131. Of the species of priming employed, 132. Of the material of which the gun is composed, 133. Of the temperature of the gun, 134. Of the size and form of the grain, 135—137. Of the equality of grain and its freedom from dust, 138. Of the influence of glazing, 139. Of the density of the grain, 140. THE EFFECT OF GUNPOWDER IN CANNON, AND ITS VALUATION—Preliminary ideas, 141—151. Of the influence of the length of bore, 152. Of the ratio of the charge in the gun, 153. Of the amount of windage, 154. Of the shape and capacity of the place which contains the charge, 155—160. Of the calibre of the gun, 161, 162. Of the resistance to be overcome, 163—166. SPECIES OF GUNPOWDER, 167—171. THE PROOF OF GUNPOWDER, 172—176. . 53

CHAPTER V.

OF PROJECTILES.

The figure of projectiles, Art. 177. Reasons for adopting this figure, 178—180. Advantages of a spherical figure, 181—184. Windage, 185. Classification of projectiles, 186—188. Compound shot, 189. Hollow shot, 190. Shells, 191—193. Grape, 194. Other forms of shot, 195. Fabrication and proof of projectiles, 196. 109

CHAPTER VI.

THEORY OF PROJECTILES.

Of the trajectory, Art. 196. Discussion of the phases the problem of the equation of the trajectory has assumed, 197—204. Initial velocities, methods of determining, 205—215. Form of the trajectory, 216, 217. Of the deviating force, 218. Angle of greatest range, 219, 220. Effect of the reaction of the air from a surface upon the projectile, 221. Ricochet firing, 222. War rockets, 223. 121

CHAPTER VII.

OF POINTING AND FIRING CANNON.

Definition, Art. 224. Point-blanc, 225. Aim at an elevation, 226. English definition of point-blanc, 226. Difficulty of pointing guns at sea, 227. Description of tangent sight, 228. Mode of using it, 229. Firing guns, 230—233. 134

CHAPTER VIII.

OF THE TANGENT SIGHTS IN USE—THEIR EMPLOYMENT AND UTILITY.

Motion of projectiles, Art. 234, 235. Utility of tangent sights, 236, 237. Invention, 238. Mode of graduation, 239, 240. Other modes of ascertaining the elevation, 241. 142

CHAPTER IX.

EXAMINATION OF THE CAUSES OF INACCURACY OF FIRE.

Effects of the rotation of the earth, Art. 242—247. General causes of deviation, 248. When caused by the position of the line of sight, 249, 250. Extent of lateral deviation, 251. Deviations caused by the enlargements, 252, 253. Deviations caused by want of sphericity, 254—256. The influence of the motion of rotation, 257, 258. Deviations due to a want of homogeneity, 259—261. Case in which the rotation produces no deviation, 262—265. Hollow shot, 266. Nature of the deviating force, 267, 268. Influence of the wind, 269, 270. Influence of the barometric state of the air, 271. Influence of refraction, 272. Causes affecting the extent of deviation, 273. Effect of the ship's motion on the deviation, 274, 275. 149

CHAPTER X.

CONCENTRATION OF FIRE.

Definition, Art. 276. Advantages to be derived, 277. Facility of concentration, 278. Means to be employed, 279, 280. Calculation of the angles, 281, 282. Limit of distance at which it should take place, 283. 164

CHAPTER XI.

THE EFFECTS OF PROJECTILES.

Probability of striking the target, Art. 284. Ricochet firing, 285. Penetration, 286. Influence of the hardness of the projectile, 287. Influence of the velocity, 288. Relations of the hardness of the projectile and the body struck, 290. Effect of impact upon iron, 291. Effect of impact upon masonry, 292. Influence of calibre, 293. Necessity of penetration, 294. Required penetration, 295, 296. Advantages of solid shot, 297. Effects of hot shot, 300. Effects of grape shot, 301. . 169

CHAPTER XII.

GENERAL PRACTICAL DEDUCTIONS FROM THE PRECEDING CONSIDERATIONS.

Of atmospheric resistance, Art. 302—306. Effect of different modes of firing and of ramming the charge, and of the weight of the gun upon the velocity, 307. Of the time of flight, 308. Of excessive charges, 309. Of the length of guns, 310. Of the use of wads, 311. Of the vent, 312. Of percussion primers, 313. Of the size of grain, 314. Of the windage, 315. Of ranges, 316, 317. Accuracy, 318, 319. Penetration, 320. 182

CHAPTER XIII.

ON THE ARMAMENT OF SHIPS OF WAR.

Opinions formerly entertained, Art. 321. Advantages of calibre, 322. Conditions to be fulfilled, 323. Total weight of battery, 324. Individual weight of guns, 325, 326. Armament for different classes of vessels, 327, 328. Number of guns, 329. Calibre, 330—332. . . 187

PRACTICAL INSTRUCTION.

CHAPTER XIV.

NOMENCLATURE OF GUNS, THEIR CARRIAGES AND EQUIPMENTS, AND OF THE IMPLEMENTS USED IN THE SERVICE OF GUNS.

Nomenclature of the gun, Art. 334. Of the gun-carriage, 335. Of the equipments, 336. Of the implements, 337. 194

CHAPTER XV.

PREPARATION OF GUNS, GUN-CARRIAGES, AND MATERIAL FOR SERVICE.—SERVICE OF GUNS.

Of the guns, Art. 339. Of the equipments, 340. Of the shot, 341. Of the shells, 342. Of grape and canister, 343. Of wads, 344. Of proportioning charges, 345. Of percussion primers, 346. SERVICE OF GUNS—Sponging, 347. Loading with cartridge, 348. Shot, 349. Shells, 350. Double shotting, 351. Grape, 352. Ranges, 353. Ricochet, 354. 203

CHAPTER XVI.

INSTRUCTION AND GENERAL DETAILS.

Preliminary remarks, Page 222. Stationing the men, 223. Assembling at quarters, 225. Clearing for exercise, or action, 226. Gun exercise, 228. Notes to the gun exercise, 231. Exercise of chambered shell guns, 234. Notes to the shell gun exercise, 235. Magazine exercise, 235. Supplying shot and shells, 237. Securing the guns, 238. Shifting carriages, 238. Shifting from port to port, 239. Shifting breechings, 239. Shifting trucks, 239.

Practice Tables, ... 214

THEORY AND PRACTICE

OF

NAVAL GUNNERY.

CHAPTER I.

DEFINITIONS AND INTRODUCTORY REMARKS.

Introductory Remarks.

1. Before entering upon the discussion of the principles which govern the construction of guns, and the manufacture of gunpowder and projectiles, we will examine the conditions which they should satisfy in their employment, and define certain terms used in the following pages.

A resumé of the most important principles of physics, which should guide us in the selection of materiel of such importance, will not, it is presumed, be misplaced.

It is indispensably necessary that we should be familiar with these principles, for we have frequently neither the time nor the means to enable us to determine by experiment, the real or apparent advantages of a proposed system. A knowledge of chemistry is indispensable for the fabrication of gunpowder, and accurate determination of its effects;—of physics, to determine the force developed by the inflammation of the charge, and the strength of the substances which

enter into the construction of the materiel of artillery,—and of mathematics, to calculate the resistances to be overcome, to determine the velocity of the projectile, the curve which it describes, and its force of penetration.

Thus, theoretical researches, however indirect they may at first appear, throw light upon the science, show the absurdity of the vulgar ideas, prevent the necessity of constantly recurring to the slow and uncertain track of experiment, and in their application facilitate practice. It is true, that these advantages are not immediate, but they are not the less valuable; and the moment we abandon the study of the principles, our knowledge of the art decays. Theory naturally follows the track of experiment, being an attempt to explain the causes which produce the phenomena which we have observed; our theories must, however, be based upon an accurate knowledge of the general laws of nature, for our individual experience may be at variance with established laws, and is liable to all the errors of ignorance and prejudice.

Physical laws.

2. A phenomenon is any change whatever in the state of a body; it is a sensation, or the effect of an impulse, of which we must ascertain the cause. To ascertain this cause, we should first endeavor to discover the laws which these phenomena obey; that is, the constant relations which exist between causes and their effects.

3. It is not always easy to deduce these laws from the phenomena; for they are in general the result of a complication of simultaneous effects of several natural forces. It is therefore necessary that we should be able in the general effect, to discover the part which is due to the cause or particular force which we are considering.

Experiment, which consists in isolating as much as possible each pair of causes and effects, is in such cases an important aid to the philosopher. *Observation*, which consists in the study of such phenomena as accidentally present themselves, and with all their complexity, less frequently leads to a knowledge of their laws: but there are many cases where observation is the sole guide which we are enabled to obtain. Occasionally, in lieu of experiment, we have recourse to *analogy* to draw more or less reliable deductions from the identity of causes. Laws thus deduced from experiment, observation, and analogy, are termed *empirical laws*.

4. When these empirical laws can be expressed in numbers, we may submit them to calculation, and mathematical analysis will determine all the consequences which may be derived from them. The agreement of the results deduced by calculation, and those furnished by experiment and observation, confirms the laws assumed; but it is not until after several series of coincident results that they can be considered as fully established. The enunciation of this law, and the development of the consequences derived from it, constitute an explanation of the phenomena dependent upon it;—this explanation is denominated the *theory*. In general, then, we are to understand by the *theory*, all the laws by means of which we can explain the mutual relation which exists between the effects and causes of a certain class of phenomena.

Since these laws are in general but the corollaries of a single law, mathematical analysis is an indispensable aid in its discovery.

Definitions. Matter.

5. That which can in any manner whatever affect our senses, is termed *matter*.

Bodies, are such portions of matter as are bounded

in every direction; they must consequently possess a determinate *figure* and *volume*.

Force. 6. By the term *force*, we denote any cause acting upon matter to produce motion, or which only tends to produce it, when its effect is prevented or interrupted by any other cause. Forces, with regard to the duration of their action, are divided into instantaneous or impulsive and permanent. The former are such as act for an instant upon the body set in motion and then cease; the latter, on the contrary, continue in operation for some given time without cessation. When a body, although solicited by several forces, remains at rest, we say that the body is in *equilibrium*. Rest, therefore, requires that the intensity of the forces, their direction, and the points of their application, shall satisfy certain conditions.

Action and reaction. 7. The force developed is always equal to the resistance which it meets with in the direction of its action; hence the action of a force produces in a body a quantity of motion (Art. 10) which is equal to the force exerted. This law is expressed by saying, that "*action and reaction are equal to each other, and in opposite directions.*"

Velocity. 8. The term *velocity* denotes the ratio of the number of units of space passed over, divided by the number of units of time employed; or, in other words, the space passed over in the unit of time. The velocity may be either uniform or variable; the first is produced by the action of a single or several simultaneous impulsive forces; the second, by the action of a permanent force.

In gunnery, the term *initial velocity* means the velocity with which a projectile leaves the gun; *remaining velocity*, the velocity it has at any point of its flight; and *final*, or *striking velocity*, that which it has at the point of fall.

Mass.

9. When the same impulsive force acts successively upon different bodies, it does not always impress the same velocity upon each of them; in general, forces of different intensities are required to cause these bodies to acquire the same velocity. If, however, under these circumstances two bodies receive from the same quantity of force the same uniform motion, we express this relation by saying that the *masses* are equal; that is, that they contain the same number of material particles, or ultimate atoms, into which all matter is supposed to be divided. The ratio of the masses of bodies may be measured by the ratio of the quantities of force of the same nature which impress upon them the same velocity. The expression for this law is, "*the impulsive forces are proportional to the masses upon which they impress the same velocity;*" from which we deduce the corollary, that *the forces are proportional to the velocities which they impress upon the same mass.*

Momentum, or measure of forces.

10. Thus two forces impressing equal velocities upon different masses, are to each other as the masses; and two forces giving different velocities to equal masses, are proportional to the velocities. Hence we may infer, that the forces F, F′, impressing upon two masses M, M′, velocities V and V′, are to each other as the products M V, M′V′. The product M V, which is called the *momentum* or *quantity of motion*, may therefore serve as a measure of the force; if this force F, act upon a mass M′, different from M, it will impress upon it a velocity V′, which will be determined by the equation $M V = M' V'$, or $V' = \frac{M V}{M'}$. The intensity of the moving power is therefore estimated by the mass and velocity of the body set in motion.

Impact of bodies.

11. When a body is once set in motion with a given velocity, its motion can only be destroyed by the

Impact of bodies:

action of some external cause; if this cause is the interposition of some other body in the direction of motion, a collision of the bodies or impact takes place. If the body interposed be immovable, or if its mass be very great as compared with that of the moving body, and both bodies are non-elastic, they will remain at rest after impact; and, if the force of the moving body be sufficiently great to overcome the cohesion subsisting between the particles of the body impinged on, it will penetrate the one at rest until the resistance offered by the cohesion of the particles of the latter equals the momentum of the penetrating body; the effects produced by different bodies, and *the depths penetrated will be as the squares of the velocity multiplied into the mass of the moving body.* Let P, represent the depth of penetration, and we have the proportions,—

$$P : p = M V^2 : m v^2$$

$$\text{if } M = m, \quad P : p = V^2 : v^2$$

$$\text{if } V = v, \quad P : p = M : m$$

General properties of bodies.

12. All bodies are possessed of certain general properties, which may be divided into two classes; those which are essential to their existence, and those which are non-essential.

Essential.

13. The essential properties of bodies are *extension* and *impenetrability.* Extension is that property in consequence of which every body occupies a certain limited space. It is necessary to the mathematical idea of the body; by it, the *volume* or size of the contained space, as well as its *figure* or boundary, is determined. The extension of bodies is expressed by the three dimensions, length, breadth, and thickness.

The second general property of matter, essential to its existence, is impenetrability; which is evinced by the fact, that a second body cannot enter into the

space occupied by another body, without previously thrusting out the first.

Non-essential.

14. In addition to the essential properties of bodies, they are possessed of others which are non-essential; that is, we could conceive of the existence of matter deprived of these properties. Among the most important of these are *mobility*, *inertia*, *gravity*, and *weight*.

Mobility.

15. All bodies are *movable*, but matter never moves spontaneously; for there is no reason why it should take one direction rather than another, therefore motion is the effect of a foreign cause, and can never be produced by matter itself. Motion is the state of a body which successively occupies different places in space: it may be absolute or relative motion, but as we can only judge of the state of rest or motion of a body by comparing it either with other bodies, or with ourselves, on this account all the motions we observe are necessarily relative motions.

Inertia.

16. *Inertia* is the impossibility which exists in bodies of exciting motion in themselves, or of changing the motion which has been communicated to them. This term does not imply that matter is incapable of acting, but merely that the *cause* of the action is not in itself. Inertia evidently exists in a body at rest, but we do not so readily admit its existence in a body in motion, for we observe that all bodies finally attain a state of rest. Upon attentively considering the subject it becomes evident, that in proportion as the obstacles to the motion of bodies, such as friction and the resistance of the media in which they move, diminish in intensity, the longer they continue in motion; therefore we may conclude that if a body set in motion met with no disturbing cause, it would continue in that state. The term *force of inertia* is sometimes inaccurately employed to denote the sensation of effort which is experienced in setting a body in motion: this

sensation is not due to the inertia of the body, but to the force employed ;[1] for, if it were not for the resistance from friction, the most feeble effort would communicate motion to the greatest mass.

Gravity. 17. It is well known that all bodies have a tendency to approach or attract each other; but since the attractive power of the earth, by reason of its mass, is infinitely great, as compared with the attractive forces of bodies on its surface, it renders insensible the mutual attractions of all other bodies. The attractive power of the earth is called the attraction of gravitation, or simply, the force of *gravity*. This force acts upon all bodies in the direction of the vertical, because the resultant of the attractions of all the particles of which the earth is composed is in that line; hence every body not supported, or deprived of what supports it, falls towards the centre of the earth in the direction of its line of gravity. The force of gravity acts with equal intensity upon all bodies at the same place, whether at rest or in motion, but varies in intensity at the surface of the earth with the latitude; and in the same latitude it likewise varies with the elevation above the surface; for, the attractive force is directly as the masses of the bodies and inversely proportional to the squares of their distances.

As gravity is a permanent force, the descent of bodies, which is due to this cause, is necessarily a uniformly accelerated motion; that is, the velocity increases in an arithmetical progression;—for, supposing the body set in motion; it has on beginning to move a velocity $= 0$, and at the end of the first second of time it will have acquired a velocity $= v$; if then the motion is continued, the body, in consequence of its inertia, preserves the velocity it has acquired, besides

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[1] Poisson, Traité de Mécanique, art. 120.

which gravity acts upon it as in the first second, so that at the end of the 2d second it will have acquired a velocity $= 2$ v; hence it follows that the spaces fallen through in given intervals of time increase as the squares of the times. Gravity.

As gravity operates with equal intensity upon all bodies, that is, every individual atom of a body is attracted equally towards the earth, all bodies not retarded by some external cause must fall with equal velocities.

18. *Weight* is the result and the measure of the force of gravity; thus if a fixed obstacle prevents the fall of a heavy body, it sustains a pressure equal to the force of gravity upon that body. This pressure being the resultant of the force of gravity upon each particle of the body, it follows that the weight of any body is in a ratio compounded of the mass and of the intensity of gravity at the place where it is situated; the weights of bodies therefore serve to measure their masses. Weight.

The force of gravity is also measured by the velocity in linear units which it will cause a body falling freely to acquire at the end of one second of time. At Washington the force of gravity is 32.155 feet.

19. The *specific gravities*, or *densities* of bodies, express the relation of mass to volume. Thus the relative weights of equal volumes expresses the *density* of matter; the more any body weighs, with equal volumes, the denser it is. This density of bodies is usually expressed in numbers, that of distilled water being assumed as unity, and the particular weight of each substance is called its *specific gravity*. As all matter admits of compression and expansion, it follows that the specific gravity of the same substance varies with circumstances. Density.

20. As references to the remainder of the general

properties of matter are not requisite, we will resume the discussion of the action of forces, the principal effect of which is to generate motion.

A cause must always exist for motion; during the continuance of the motion a certain time must necessarily elapse; and lastly, the moving body must pass over a certain distance in a definite direction, which will depend on the causes of its motion.

Mode of representing forces.

21. All forces may be considered as magnitudes which can be measured by the effects they produce; their intensity is expressed by numbers, or by lines proportional to such numbers, taken in the direction of the motion. When two or more forces act in the same direction, they combine their effects: if they act in contrary directions, the effect is equal to the difference of the forces. If the forces are equal, and directly opposed, they mutually destroy each other, and the body is in equilibrium.

Uniform motion.

22. When a body receives an instantaneous impulse, it takes up a uniform motion in a straight line; that is, it passes over equal spaces in equal times; there are therefore three things to consider in uniform motion,—space, time, and velocity; quantities of different species, which should be referred to different units, that we may compare the numbers which represent them.

If the body is subjected to the simultaneous action of two instantaneous forces which form an angle with each other, it takes an intermediate direction, and will describe the diagonal of a parallelogram, of which the lines representing the forces form the sides. This principle is called that of the parallelogram of forces.

Variable motion.

23. If, however, the velocity is rendered variable by the action of a permanent force, the direction can only be considered constant for an infinitely short period of time; the line described is therefore represented by

a polygon of an infinite number of sides, that is, a curved line convex towards the direction of the impulsive force. The algebraic relation of all the points of this line is called the equation of the curve; by solving this equation, we can determine the position of these points, and construct the curve. The curve described by the projectiles of artillery is called the *trajectory;* the resolution of its equation is rendered difficult, from the variable nature of one of the forces acting upon the body during its flight.

Parabolic theory.

24. The parabolic theory, which is the basis of all the methods proposed for the resolution of the equation of the trajectory, assumes that a body has been subjected to an instantaneous impulse of determinate force and direction, and that it is also acted upon by the force of gravity. Under the influence of the first of these forces, the body would pass over equal horizontal spaces in equal times, but since gravity is a constantly accelerating or retarding force, the vertical spaces would be to each other as the squares of the times.

The body consequently describes a curve, the points of which bear a very simple relation. According to this theory, the lightest bodies attain the same distance as the heaviest, if fired with the same velocity and at the same angle. For example, a ball of cork would have the same range as a leaden one. We may perceive by this assertion, so opposite to observed facts, how far the hypothesis is admissible.

Nevertheless, if the velocity is low, the projectile of great density, and the range short, the resistance of the atmosphere is greatly diminished, and the parabolic theory differs but little from the truth.

Law of atmospheric resistance.

25. Experiment shows that balls fired in the air with great velocity do not attain one-fifth the range they should by the parabolic theory. For a long pe-

Law of atmospheric resistance.

riod this was attributed to the unskilfulness of artillerists; but Gallileo demonstrated that the defect should be attributed to the resistance of the atmosphere. The resistance being admitted, we should endeavor to determine its amount. It ought evidently to be a function of the velocity of the projectile, but it is difficult to arrive at the nature of the function. It is, however, generally assumed to be proportional to the surface of the body and the square of its velocity. It is unnecessary to give the reasoning which leads to this result, for we must admit that the greater the surface, the more difficult will it be for the condensed air to escape, and a greater volume will be driven before the projectile; consequently, the resistance of the atmosphere cannot be proportional to the surface of the projectile. Some experiments upon this subject would seem to show that the resistances increase as the 2.18 powers of the diameters.

The resistance also increases in a more complicated ratio than the square of the velocity; for this law assumes that the particles struck are annihilated, whilst in reality the projectile drives before it a mass of condensed air, and leaves behind a partial vacuum, into which the displaced air flows, producing eddies which favor the motion. As the velocity increases, up to a certain point, the resistance also increases, being partly caused by the increased length of the column of condensed air, and also by the increased friction.

When the velocity is greater than that with which air flows into a vacuum, the projectile leaves a vacuum in its rear, but nevertheless the resistance increases very slowly from this point; it is supposed that the eddies occasioned by the suction of the vacuum diminish the resistance; thus the value of that part of the co-efficient depending upon the velocity is the same for 1400 feet as for 1900.

26. The form of the surface exercises a great influence upon the resistance, and much labor has been expended in determining the figure of the solid of least resistance, but for various reasons discussed in Chap. V. it is necessary to give the projectiles of artillery a spherical figure; the problem is consequently narrowed down to the determination of the conditions of least resistance for a sphere. Figure. Plate I. Fig. 5.

27. The momenta of shot are proportionate to their diameters multiplied by their densities. Therefore, for projectiles of the same density, the effects of atmospheric resistance are in the inverse ratio of their diameters; if the projectiles are of equal diameter, the effect will be in the inverse ratio of their densities.

For example,—if we double the density of the projectile, we reduce the effect of atmospheric resistance one-half; we may even effect the same reduction by leaving the density constant, and doubling the diameter of the projectile;[1] but in this case the mass and weight of the projectile, which increase as the cube of its diameter; become eight times greater, whilst in the first case the weight is but doubled—consequently the denser projectile is but one-fourth the weight of the other; for these reasons it is more advantageous to give projectiles great density than to increase their diameter.

28. By the preceding reasoning it is shown that the resistance is represented by some function of the diameter and density of the body, and the density of the atmosphere multiplied by a variable co-efficient depending upon the velocity. This co-efficient represents the ratio of the resistance of the atmosphere to the weight of a cylinder of air having a base equal to Form of function.

[1] This principle is applied in the employment of shells, which are made of great diameter, to compensate for their want of density.

the great circle of the ball and a height due to its velocity.

Nature of the forces.

We have therefore three forces acting upon the projectile; first, an instantaneous impulse, which would cause it to describe equal spaces in equal times; secondly, the force of gravity, which causes it to describe vertical spaces which are as the squares of the times; thirdly, atmospheric resistance, which acts tangent to the trajectory, and varies during the continuance of the motion.

Definitions.

29. The trajectories are said to be similar when their *amplitudes* are proportional to the heights of the curves which they describe. Experiment and analysis both show that the trajectory changes its form in but a slight degree within the limits of 0° and 15° above or below the horizontal plane. The problem is therefore divided into two species:—1st, direct fire with high velocities and at a small angle of elevation; 2d, the projection of bombs.

The *amplitude* of a curve signifies the range of the projectile, or the horizontal line subtending the curvilinear path in which it moves.

Angle of elevation; angle formed by the axis of the gun and the horizontal plane.

Angles of projection or *departure*, and *Angle of incidence;* angles formed with the horizontal plane by the tangents to the trajectory at the origin of the curve and the point of incidence. The angle of elevation should be carefully distinguished from the angle of departure, because the shocks experienced by the projectile cause it to depart from the direction of the axis of the gun. According to Lombard, the mean difference is 10′, extreme 34′.

Plane of fire; a vertical plane, passing through the axis of the gun.

Natural line of sight or *line of metal;* a line in the vertical plane tangent to the base-ring and swell of the muzzle, and constant for the same gun. Definitions.

Artificial line of sight; a line in the vertical plane tangent to the most elevated points of the tangent scale and front sight. This line makes a variable angle with the axis, depending upon the elevation of the tangent scale.

The *Dispart* of a gun is half the difference of its diameter at the base-ring and at the swell of the muzzle. By placing upon the muzzle a piece of metal equal in height to the dispart, the line of sight will be made parallel to the axis of the bore.

Angle of sight, natural or artificial, formed by the axis with the line of sight, whether natural or artificial. The natural angle of sight is sometimes termed the *angle of dispart.*

Natural point-blank or *line of metal elevation;* the point where the trajectory intersects the second time the natural line of sight, the latter being horizontal.

Point-blank range; the distance from point-blank to the muzzle of the gun. All other things being equal, the range increases with the angle of sight, and within the limits of the range it is always possible to select such an angle of sight as will permit us to reach any given point.

CHAPTER II.

OF ARTILLERY IN GENERAL.

Classification.

30. Cannon may be divided into three classes: the first class comprehends those used in the attack and defence of fortified places; the second, field-artillery; and the third, those which are employed for harbor-defence and the armament of ships of war. It is these last only which we are about to consider.

Exterior figure.

31. Cannon in general have the form of a truncated cone, hollowed cylindrically in the direction of the axis to a certain depth, the strongest part corresponding to the position of the charge. This figure is evidently given to enable it better to withstand the effect of the charge, which acts equally on all sides, but is constantly diminishing as the projectile approaches the mouth of the piece.

Interior figure.

A cylindrical figure, that is a constant size, has been given to the bore of all cannon, in order not to increase the loss of the elastic fluid already occasioned by the vent and the windage which it is necessary to give the projectile; and at the same time to diminish the violence of the shocks against the interior; thereby preserving the gun and rendering the fire more accurate.

Ratio of weight to that of the projectile.

32. As it is admitted that no force can act without having some point of resistance, it is evident that in firing a gun, the bottom of the bore is reacted upon

by a force equal to that which drives before it the projectile and the charge itself; for, as we will show, the inflammation of the charge is not instantaneous. We may then conclude, that if the gun is of the same weight as the projectile, it will take up motion in a contrary direction with a velocity proportionally greater as the charge is heavier. This excess of velocity is due to the weight of the charge, the gases of which continue to re-act upon the bottom of the bore after the projectile has left the gun.

Recoil.

33. This retrograde movement impressed upon the gun by the effort of the charge, is called the recoil, and should be kept within certain limits, that the service of the gun may be convenient. The recoil being produced by the re-action of the gases which are produced by the combustion of the charge upon the bottom of the bore, this re-action is measured by the sum of all the resistances which are met by the elastic fluid in putting the projectile and charge in motion. But the velocities given to these bodies are generally so great, that they have already left the gun before its inertia has been overcome; and we may assume the principle, that the recoil does not sensibly alter the line of direction, even for medium charges; this is due to the length of the gun and its recoil in a straight line.[1]

Measure of recoil.

34. We learn in mechanics, that the velocities of bodies are in the inverse ratio of their masses; if then we make the gun 250 times heavier than its shot, the recoil will not exceed $\frac{1}{250}$ of that which it would have by the first hypothesis. Very light guns have a great recoil, rack and quickly destroy their carriages; very heavy guns have easy recoil, but are deprived of faci-

[1] Simmons asserts that experiments at Woolwich have shown that the line of direction is affected by the inequalities of the platform on which the gun rests.

lity of manœuvring, a quality so essential to their use in service. It is therefore necessary that the weight of the gun should bear a certain relation to that of the projectile and the charge, determined by the service for which it is destined.

Nomenclature.

35. The exterior of a gun is divided into five parts. 1st. The *cascabel*, or the portion in the rear of the base ring; this is composed of the *base of the breech*, and *pomillion*, or *neck* and *knob* of the cascabel. 2d. The *first reinforce*, measured from the rear of the base ring to the base of the first cone. The *vent patch*, a mass of metal, to which the lock is attached, is placed in this part in advance of the base ring. 3d. The *second reinforce*, is the first cone. The *trunnions*, with their *rimbases*, are attached to the gun near the extremity of the second reinforce. 4th. The *chace* is the second cone, extending to the rear of the muzzle ring. 5th. The *muzzle*. This part is composed of the muzzle ring, the *tulip*, or swell of the muzzle, and the face of the muzzle.

The interior is divided into, the *bore*, the *slope* of the *chamber*, the *chamber*, and the *vent*; carronades have a *flash rim*, or increase of size of the bore at the muzzle; this increases the length, and, on board ships, protects in a measure the rigging from the blast.

36. The calibre of a gun is usually expressed by the weight of the solid shot in pounds. In the long guns lately introduced, by the diameter of the *bore* in inches. (In England by the diameter of the shot.) The diameter of the bore is always a little greater than that of the projectile, that the latter may enter easily, and that the service of the gun may never be interrupted by its jamming. This difference between the diameter of the projectile and that of the bore, is called

Windage.

windage. Several reasons oblige us to give projectiles

a certain amount of windage which we are unable to reduce. For, it is in the first place impossible to cast projectiles which shall be of the exact diameter, and perfectly spherical; the diameter of the projectile is increased by rust, or when it is heated; in prolonged firing, the foulness of the bore diminishes its diameter; with shells, the thickness of the straps which attach it to the *sabot*, increase their diameter. Windage diminishes the accuracy of fire, permits an escape of gases, which diminishes the effect of the charge, and is also the principle cause of the deterioration of cannon. Windage.

37. When a light gun is intended to throw heavy projectiles, we can only diminish the recoil by employing small charges of powder; but as these charges occupy but a small space, and are with difficulty kept in their proper place, the bottom of the bore is contracted into the form of a truncated cone, or *à la Gomer*, a cylinder, or a sphere. Chambers for powder—their figures and properties.

The effect of a chamber depends principally upon its figure, and the size of its orifice. Thus, in spherical chambers, the force being developed in the smallest possible space, and its action being against but a small segment of the projectile, produces the greatest possible effect.

38. Spherical chambers consist in a portion of a cylindrical chamber, terminated by a sphere of a considerably greater diameter. The first part of the chamber serves as a channel for the escape of the gases; these will escape with greater difficulty, as the cylindrical part is of a less diameter; thus spherical chambers have the greatest effect, but they have the inconvenience of breaking the projectile, and straining the gun, which has caused their abandonment. Pear-shaped chambers have the same defects in a nearly Spherical and pear-shaped chambers. Fig. 3, Pl. I.

equal degree, and both kinds are very difficult to sponge and cleanse.

Cylindrical chambers. Fig. 1, Pl. I.

39. Among cylindrical chambers, those which are narrow and deep, give longer ranges than those which are of slight depth and wide slope; but they have the disadvantage of sometimes breaking their shot, because the action is against but a small segment of their surface; an inconvenience to which other forms are not liable, particularly conical chambers, where the force of the charge is exerted upon nearly a hemisphere.

Chambers in the form of a truncated cone. Fig. 2, Pl. I.

40. The effort exerted by the charge is the greatest when the aperture for the escape of the inflamed gases is most contracted, but although the elastic force diminishes when the orifice is increased, it may happen that there will be no disadvantage from this augmentation; this occurs in truncated-conical chambers, in which the projectile receives the impulsion upon almost a hemisphere, and they frequently produce a greater effect than cylindrical chambers; they do not rack the gun or its carriage, and are superior in accuracy of fire to all others.

Other forms of Chambers.

41. Besides the four kinds of chambers above mentioned, several others have been contrived, such as the parabolical, elliptical, &c., to which properties have been attributed that subsequent experiment showed did not exist, or which were rejected on account of their defects, or the difficulty of exercising them.

Influence of the chamber.

42. For small charges, the use of a chamber is always advantageous, whatever may be the length of the gun; for, the chamber being less than the great circle of the bore, less of the force of the charge is lost by windage; but the advantage is more marked as the gun is shorter. As the length of the gun is increased, and the charge augmented, the influence of the chamber becomes less sensible, and the point at which its

influence becomes insensible, is at a length of ten to twelve calibres, and a charge of $\frac{1}{8}$ to $\frac{1}{6}$ the weight of the projectile. The most advantageous proportion between the length and diameter of a chamber, would appear to be **3** to **1** (vide Thiroux). Influence of the chamber.

43. In long guns, the presence of a chamber diminishes the velocity by lengthening the charge, and diminishing the rapidity of its inflammation.

In most cannon, the bottom of the bore, or of the chamber, is terminated by a plane connected with the adjacent surfaces by arcs of a circle; this arrangement favors the cleansing of the bore, and gives greater strength to the breech.

44. A gun can sustain but a certain number of discharges without being seriously impaired;[1] this number depends upon the material of which the gun is composed, thickness of metal about the bore, length of the gun, mode of fabrication, charge of powder, and interval between the discharges. At first, the vent is enlarged; afterwards, the bore enlarges and receives deep indentations from the blows of the projectile—and in bronze cannon, if the fire is rapid and long-continuous, the chase bends. In cast-iron guns, after a long-sustained fire, the vents become irregular, run, or are gullied; and it has been observed, that when a gun bursts, the plane of rupture generally passes through the vent. Durability of cannon.

45. The thickness of the metal should be proportionate to the force developed by the charge; and this thickness being once fixed, the length of the gun results from the weight which it is necessary to give it. Their exterior surface is generated by the revolution

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[1] This number is, for iron guns, usually estimated at 1000. At the siege of Badajoz, several 24-pounders were fired upwards of 3000 times without accident or material injury to the guns.

of different lines, more or less inclined with respect to the axis, following certain rules determined by experiment.

Thickness of metal.

In order to determine by theoretical considerations the thickness of metal which ought to correspond to different points of the length in the same cannon, and the proportions which these thicknesses should follow in the different calibres, it would be necessary for us to know by what law powder inflames,—also that of the resistance of metals; to compute the degree of heat in the piece, and the nature of the shocks the bore receives from the ball.

As the requisite data are not known, it is necessary to have recourse to hypothesis and the aid of experiment. It was therefore supposed that the inflammation of the powder, if not instantaneous, was so rapid, that all the charge was inflamed before the projectile was sensibly moved from its place; experiment proved that the proportions deduced from this hypothesis gave cannon a sufficient solidity and durability.

According to the hypothesis of a very rapid inflammation, the powder exerts its greatest effort at the instant the projectile is displaced, and this effort is sustained by the metal surrounding that part of the bore which contains the charge; the other parts sustain no pressure until the projectile reaches them, and the pressure is then less than at first, because the force of the elastic fluid diminishes in proportion as it expands into a greater space. Hence it may be inferred, that the greatest thickness ought to be found surrounding the charge, and to decrease progressively to the muzzle. Upon this supposition, it can be demonstrated that the profile of a cannon would be a hyperbolic curve.

Swell.

46. It has, however, been found necessary to add the swell of the muzzle to reinforce that part which

has to sustain the shocks given by the projectile on leaving the gun; for these shocks become more violent as they happen nearer the muzzle. If it were not for these shocks, we could in iron guns, where a lodgment is formed very slowly, and the enlargements are slight, reduce the thickness of the muzzle to $\frac{1}{3}$ the diameter of the projectile, which would give us the advantage of greater projection from the port, by bringing the trunnions nearer the breech. Swell.

47. Some authors, and particularly Sir William Congreve, have asserted that the external form or shape of a gun influences the range of the projectile fired from it; or, to use his language, "The propelling power of a piece of ordnance may be increased by increasing the quantity of metal about the charge, though it be taken away from other parts; and, consequently, that a lighter gun may have greater propellant power than a heavier gun, by a more judicious application of the metal of which it is composed."

As the propelling power is dependent entirely upon the charge, and its proper combustion, which is evidently not affected by the external figure, and the inertia of a mass is the same, whatever may be its form, the fallacy of this assertion is too apparent to mislead. The experiments upon which he based his theory were only calculated to mislead a superficial observer; and the greater ranges to which he appeals in support of his assertions, may fairly be attributed to a jerking of the breech, or circular recoil around the trunnions, well known to exist in guns of great preponderance.

48. Guns destined for service in the field are of bronze,—those used at sea and upon fortifications, are generally of cast-iron. Bronze cannon cost much more than those of iron, and are quickly injured by Material of which guns are composed.

Material of which guns are composed.

the effects of firing, particularly those of heavy calibre; but the security which they offer in service, has caused their retention. Iron guns have the advantage of little cost, and of being very slowly injured by firing; they are, however, liable to burst without any indication on the exterior to show that the cohesion of the metal is destroyed. Thus it sometimes happens that cannon which have sustained very heavy charges have afterwards burst with smaller charges, because the action of the latter has been sufficient to complete the destructive effect of the preceding charges.

49. It has been observed, all other things being equal, that iron guns give a little greater velocity to their projectiles than those of bronze, which is perhaps due to the imperfect elasticity of bronze; while iron guns, by virtue of their want of elasticity and great hardness, permit the force to act with all its energy. In the second place, iron is a worse conductor than bronze; it absorbs less heat, and the gases have a greater tension. The greater or less conductibility of the substance of which the gun is formed, in certain cases, particularly with small charges, exercises an influence on the range.

50. It has been proposed to manufacture bronze cannon, with a lining of wrought iron, to remedy the defects of that metal; but this has not been successful; since the different metals are of unequal tenacity, elasticity, and expansibility, and as the temperature of the sides of the bore is liable to considerable changes, the lining, in becoming more heated than the bronze to which it is soldered or merely in contact, expands more, and compresses it; when the temperature is lowered to the normal state, the lining recovers its former dimensions, but the pressure having been greater than the elasticity of the compressed metal, it no

longer returns to its former state, and a separation of the metals takes place.

Wrought iron.

51. As to wrought iron guns, the difficulty of properly welding them, particularly when they are of heavy calibre, their greater cost, and the want of elasticity in the metal, render very doubtful the advantages which some authors have attributed to them.

Trunnions, their position and use.

52. Cannon are mounted on their carriages by means of the trunnions, cylinders placed on the sides of the piece, their common axis being perpendicular to that of the gun, and around which it has a rotary motion that it may be pointed under all angles comprehended within the limits of firing. The size of the trunnions is proportioned to the force of recoil. In general they are equal in diameter and length to the diameter of the ball; this satisfies the condition of similitude, and gives them a resistance sufficiently well proportioned to the effort they must sustain. The position of the trunnions is so fixed as to diminish or favor the recoil of the carriage as circumstances may require; for, the carriage at first resisting the movement by virtue of its inertia, the gun has a tendency to turn upon its trunnions; if, then, the axis of the trunnions is below that of the gun, the breech will strike the carriage with a force proportional to the distance between the two axes, and this pressure generates a friction which diminishes the recoil. On the contrary, if the axis of the trunnions is above the axis of the gun, the breech will have a tendency to rise, a diminution of pressure will ensue, and the recoil will be increased; but the carriage, and particularly the axletrees, will be less strained. Finally, the recoil will be transmitted direct by the trunnions, if the axis is at the same height as the axis of the gun.

Plate I. Fig. 7.

53. It was thus supposed that the recoil of car-

Trunnions, their position and use.

ronades would be kept within moderate limits by suppressing the trunnions, and mounting them by means of a loop and bolt beneath the gun; mounted in this manner, they rack and destroy their carriages in a very short time, and often upset. In the United States naval service, the axis of the trunnions is always at the same height as the axis of the gun, or the gun is *centre-hung*. The French and English separate the two axes by a greater or less distance, dependent upon the proportional weight of the gun and projectile.

54. The position of the trunnions with respect to the centre of gravity of the gun, also exercises a certain influence upon the recoil.

Guns which are fired at small elevations, have the breech heavier than the muzzle, the object of which disposition of the metal is to diminish the recoil, raise the muzzle of the gun, and give it a fixed position; otherwise the reaction due to the elasticity of the carriage would, by elevating the breech, depress the muzzle, which would be inconvenient. In mortars, firing at great angles, the muzzle of the peace is heavier, to facilitate the pointing.

Preponderance.

55. This excess of weight of one part of the gun over another is called *preponderance* of the breech or muzzle. The amount of the preponderance is the pressure sustained by the elevating screw or quoin when the gun rests on its trunnions, the axis being horizontal, deducting friction. Some authors understand by preponderance the weight which should be hung at the muzzle to balance the breech; the first definition appears to me most satisfactory. The preponderance given in tables of dimensions is that founded on the hypothesis of the uniform density of the material; the real preponderance is always slightly in excess. It has been observed that guns with great preponderance al-

ways have a very lively action, or a jerking of the breech, which racks the carriage and increases the recoil.

The *rimbases* serve to strengthen the trunnions and prevent lateral motion on the carriage.

The vent.

56. The *vent* is a conical channel through which fire is communicated to the charge. As the velocity of the gas produced by the combustion of the charge is very great, it escapes in considerable quantity by this opening; and as this gas does not contribute to increase the velocity of the projectile, it follows that the effect of the charge will diminish with the increase of the vent; besides, if it is very large, it has a greater tendency to increase than if smaller, on account of the increased velocity of the gas which escapes; for these reasons, the vent has been fixed at dimensions which permit us to employ a priming-wire of sufficient size, and tubes, while recent experiments show that the loss of force by the regulated vent is inappreciable.

In general, in iron guns the vent is drilled in the mass of metal; but a bouching of copper has been proposed to remedy certain inconveniences. The amount of service experienced by an iron gun can generally be appreciated by the appearance of the interior orifice of the vent. In bronze cannon it is pierced in a conical plug or bouching of copper, a metal tougher and less fusible than bronze, and easily replaced.

57. With ordinary charges, the influence of the position of the vent with respect to the velocity of the shot and the violence of recoil, is scarcely appreciable; it should, however, be near the bottom of the bore, which is necessary to fire small charges.

Length of guns.

58. The gases produced by the combustion of the charge, form in the gun a very rapid current,

Length of guns.

which acts upon the projectile for a time proportioned to the length of the gun; if this length remains constant, the velocity will increase with the charge, but not indefinitely; for, the inflammation not being instantaneous, it must happen in certain cases that the projectile leaves the gun before all the powder has had time to ignite; and this is more likely to occur in cannon where the length of the space occupied by the charge is not proportional to the length of the bore; therefore, the longest guns, all other things being equal, produce the greatest effect. It is also known that the charge producing the maximum velocity, and this velocity itself, increase in a certain ratio as the length of bore is increased. If, however, the charge remains constant, while the length of the bore is increased, there will be a limit beyond which the velocity will diminish; because the resistance which the projectile experiences in passing along the bore, either from the condensation of the air before it, or from the shocks and friction from striking along the interior, will balance the increase of velocity due to the accelerative force of the charge.

Hence the question as to the length of bore, or charge of powder, to produce the greatest effect, involves that of the initial velocities of projectiles.

This length has not yet been determined by experiment, but probably depends on the density and hardness of the projectile, and its relative elasticity with that of the gun. It is easy to understand that the length of the bore will have less effect upon the range of the projectile: 1st, as the angle of projection is greater; 2d, as the weight of the charge is comparatively smaller; 3d, as the combustibility of the powder is increased. It has been observed, that after reaching a length of twenty-four calibres, the in-

crease of velocity which results from a greater increase of length is not in the ratio of the increase of weight.

Fabrication of cannon.

59. Cannon are cast solid, and afterwards bored; formerly the bore was formed by means of a cylinder or core placed in the interior of the mould.

The fabrication of cannon comprises the operations of moulding, casting, boring, turning on the exterior, piercing the vent, examination, and proof.

Moulding.

The mould is prepared by placing half of a model of the gun in a *flask*, or shallow box, and filling the space between the model and its sides with a mixture of refractory sand and clay, which possesses sufficient adhesion to preserve the sharpness of the mould when dried. When the flask is filled, the other half of the model is attached to the first, a second flask placed upon the first and secured, and a little sand sprinkled over the mould, to prevent the parts sticking together. The second flask is then filled; after which the model is removed, and the mould carefully smoothed with trowels.

Casting.

The mould, when dried, is placed in a pit dug at a convenient distance from the furnace in which the metal is melted, and there firmly secured. The metal from the furnace is permitted to flow into a reservoir having a communication with the lower part of the mould; when the reservoir is sufficiently filled, the communication is opened, and the metal rises in the mould; the scoria and other impurities rise to the top and form the *sprue-head*, an excess of metal at the muzzle, which is afterwards cut off.

After the casting has sufficiently cooled, the mould is taken apart, the sand scraped off, and the gun is removed to the boring-mill for the purpose of being bored.

Boring. To bore it, the axis is supported in a horizontal position, and a rotary motion given to the gun about this axis by means of machinery, while the boring-rod, also supported horizontally on a car, armed with a cutter in its extremity, is kept pressing against the gun. The metal being thus brought in contact with the hard and sharp edge of the cutter, is cut out, and a hole made in the gun. Before being bored, the sprue-head is cut off. It requires from six to ten days, according to the hardness of the metal, to bore out a twenty-four pounder iron gun.

Turning. It is at present customary to turn the whole exterior of a gun, which gives it a smoother surface and more elegant appearance than can be given in a mould. It is thought that this weakens the gun, inasmuch as the toughest and hardest metal is known to be on the exterior, or that which cools soonest. The trunnions, breech, and muzzle bands, should in all cases be turned.

Vent. The vent of iron guns is made by drilling a hole through the metal in the proper position, with a hand-drill and bit. A rotary motion is given to the bit by means of a bow and string, at the same time that it is firmly pressed against the metal.

Proof. 60. All guns undergo several kinds of proof before they are received into the service:

1st. They are gauged as to their several dimensions, internal and external; as to the justness and position of the bore, the chamber, vent, and trunnions.

2d. They are fired with a regulated charge of powder and shot, being afterwards searched to discover irregularities, or holes produced by the firing.

3d. By means of a hydraulic press water is forced into them to discover cracks, holes, and flaws.

4th. They are examined internally by means of light reflected from a mirror.

5th. A piece of metal from the sprue-head, or face of the muzzle, is subjected to experiment, to determine its tensile strength: this must exceed 22,000 pounds per square inch.

The injuries experienced by guns in service.

61. Cannon suffer more or less injury in service. In general, those of heavy calibre are most affected by a long-continued fire with heavy charges, because the tenacity and resistance of the material are constant, whilst the intensity of the destructive effect increases with the weight of the projectile and charge employed.

These injuries are of two kinds, internal and external. The elastic fluids produced by the combustion of the charge at first escape between the upper surface of the bore and the ball, and whilst this resists the movement by virtue of its inertia, the current presses it against the lower surface, and causes a depression, which becomes greater at each fire. This cavity is called a *lodgment*. There is a corresponding *burr* in front of the lodgment, formed by the displaced metal. The motion thereby given to the shot causes it to strike alternately on the top and bottom of the bore, producing other *enlargements*, generally three in number: the first, on the upper side, a little in advance of the trunnions; the second, on the lower side, near the muzzle-ring; the third, in the upper part of the muzzle. *Scratches* also are caused by the fragments of a broken shot or the roughness of an imperfect one.

In bronze cannon, *exterior cracks*, or longitudinal splits, are caused by too great a compression of the metal on the interior. The high temperature and enormous tension of the gases occasion injuries of another nature. The tin is melted, and the bronze

becomes *honey-combed* above the lodgment of the ball. The same cause occasions *cavities* and a *corrosion of the metal* about the orifice of the vent and mouth of the chamber. They are little subject to external injuries, except from the bending of the trunnions after long service or firing with heavy charges.

The injuries which have been mentioned are common to all guns; but those of iron are subject to these effects in less degree than bronze, except the corrosion of the metal, by which the vent especially is rendered unserviceable from enlargement.

62. The duration of an iron gun is generally determined by the irregularity of the vent; those of bronze by the depth of the lodgment and enlargements. The formation of these last may be retarded by the employment of cartridges of increased length and diminished diameter, and by the use of a sabot or wads of variable length, which vary the position of the ball.

Spiking cannon and rendering them unserviceable.

63. Spiking is intended to render the gun temporarily unserviceable. This is accomplished by driving into the vent a jagged and hardened steel spike with a soft point, or a nail without a head; this should be broken off flush with the outer surface, and the point clinched inside by means of the rammer or an iron bar. When obliged to retreat before an enemy, and the guns are to be spiked temporarily, a spring-spike is used, having a shoulder, to prevent its being too easily extracted.

The gun may also be rendered unserviceable by wrapping a shot with felt, and ramming it home, or wedging it with iron wedges in the bottom of the bore; burst shells in the bore of brass guns, or fire broken shot from them with high charges. Fill the gun with sand, over the charge, to burst it. Fire a piece against another, muzzle to muzzle, or the muz-

zle of one to the chase of another. Light a fire under the chase of brass guns, and strike on it with a sledge to break it. Break off the trunnions of iron guns, or burst them by firing them with heavy charges, and full of shot or sand, at a high angle.

Spiking cannon and rendering them unserviceable.

The only certain method is to burst them, as they may still be rendered serviceable in case of necessity after the loss of both trunnions and the pomilion.

In this case, or if we have no carriages, the gun may be placed upon skids, with a shore against the breech; fire with small charges, pointing with a plumb line or quadrant. We may also fire from a gun shot of a greater calibre, placed upon the muzzle;[1] this species of fire is generally at the angle of 45°: the bomb placed upon the muzzle is secured by a cord, which is broken by the first impulse; the accuracy is nearly equal to that of shells from a mortar, and the range of an 8-inch shell fired from a 24-pounder cannon, with 8 lbs. charge of powder, is about 600 yards, —the shorter the gun the greater the range.

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[1] The Austrians lately bombarded Venice by this means.

CHAPTER III.

OF GUN-CARRIAGES.

Conditions to be fulfilled.

64. Cannon are mounted upon carriages of various forms. Before proceeding to describe them, we will explain the conditions which they ought to satisfy to be of service at sea. Certain of these conditions refer to their facility of manœuvring under fire; others have reference to facility of transportation, whilst stability and simplicity of construction are of paramount importance.

65. Under fire, the carriage must yield to the force of recoil; it would quickly be destroyed, whatever might be its solidity, if it maintained a fixed position;[1] it ought then to be of a weight proportionate to that of the gun; too heavy, it would promptly be destroyed by the shocks given it by the gun; too light, it would have an inconvenient recoil. The weight of the carriage ought always to be less than that of the gun. A very heavy gun upon a light carriage always does better service than a light gun upon a heavy carriage; this is owing to the effort exerted by the gun being a function of its mass by the square of its velocity.

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[1] At Gibraltar some attempts have been made to mount guns in the rocks themselves, but the recoil either broke the trunnions or the rock gave way.

At sea, the limited space which we have at command in the rear of the battery, renders it necessary to restrain the recoil within certain limits; we see, therefore, that we ought to diminish the recoil, either by friction properly managed, or by the elasticity of cordage, and avoid shocks which are always injurious to the carriage.

66. Carriages of various forms have been proposed for adoption, in which the recoil is to be restrained by friction; these usually consist of a slide and top-carriage, the friction of the latter being increased by a clamp and compressor, to be screwed down before firing. The general objection to this arrangement is, that the crew of the gun may, in the heat of action, forget to tighten the clamps, thereby greatly endangering themselves, and probably destroying the carriage itself. The machinery is also liable to get out of order. Methods of restraining recoil.

67. In general, the recoil is restrained by the aid of the *breeching*, a piece of cordage of such length as to permit the muzzle of the gun to come within the port, and of a strength proportioned to the moment of recoil. The breeching is rove through the cascable ring, or snatched in the shark's mouth cast upon the breech in the guns of the new pattern, through the breeching shackle on the carriage, and the ends shackled to the bulwarks, on each side of the port. The breeching, as thus arranged, does not fulfil all the conditions required, because the strain upon the two legs, when the gun is fired obliquely, is not equalized. Lieut. Ward has, in connection with his carriage (art. 78), avoided this difficulty by shackling the breeching to a single bolt below the centre of the port. Plate IV. Fig. 1.

68. Col. Romme proposed for adoption with his carriage (art. 80), a compound breeching of chain Plate V. Fig. 3.

Methods of restraining recoil.

and cordage.[1] The rope portion is rove through the cascable ring, and is long enough to fit the round of the breech; a portion of chain connects each end with a single forked breeching bolt, secured below the centre of the port sill. When the gun is run out, the breeching, which is spanned together at the breast of the carriage, bends below the chase of the gun by its own weight, without requiring the care of two men of the gun's crew, and leave these last to assist at the side tackles, thereby reducing by so many men the necessary complement of each gun, without impairing its efficient service.

When firing obliquely, the breeching being fastened to only one bolt in the side of the ship, is always equally strained, and therefore is less susceptible of favoring deviations in the flight of the shot, arising from irregularity in the recoil of the carriage, a consideration not without importance.

This breeching, notwithstanding its apparent advantages, ought not to be adopted until it has been submitted to the trial of actual service, where it is liable to be struck by shot, and the pieces flying in every direction, become so many instruments of destruction.

69. Caoutchouc, or india-rubber, has also been proposed for breechings; but the commission appointed to examine it decided that it was deficient in strength, and in no wise fit for the service of naval guns. For, supposing even that the requisite strength could be procured by increasing the quantity of threads, it was probable that it would serve no better, inasmuch as the great reaction occasioned by the elasticity of the material, would soon ruin the carriage.[2]

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[1] Experiments on board the frigate Dryade, p. 23. [2] Vide do. p. 22.

70. The effect of a wheel being expressed by a function of its diameter, divided by that of the axletree, we can also diminish the recoil by diminishing the height of the wheels, or by increasing the diameter of the axletree. For this reason sea-gun carriages are mounted upon *trucks*, a species of solid wheel of small diameter; when the gun is fired, the trucks at first slide upon the deck without turning, and it is not until after a certain time has elapsed, depending upon the velocity of recoil, that they begin to rotate; but as soon as their friction is overcome, the motion becomes more uniform, and the recoil would be of considerable extent if it were not checked by the breeching. The trucks, therefore, serve to moderate the recoil and render it more uniform. Methods of restraining recoil.

71. The position of the trunnions also exercises a certain degree of influence upon the recoil; the higher the trunnions are raised above the axletrees, the longer will be the arm of the lever which presses the inner trucks against the deck, and tends to capsize the carriage, and the more will the recoil be diminished.

72. In general, the carriage must have such stability that it will not be liable to capsize when under fire, or by the pitching of the vessel; nor to fall over on its face by the rolling, or when fired to leeward; this last defect can be remedied by placing the trunnion holes some distance within the outer axletrees. It must have facility of horizontal motion, or train—and convenience of vertical motion, or elevation and depression to the extent which experience has shown to be necessary for the service for which it is destined.

73. The principles upon which the construction of gun-carriages is based are therefore: Principles of construction.

1st. To work the heaviest guns with the smallest number of men.

Principles of construction.

2d. To strain the ship the least possible by the recoil and reaction.

74. We should then in the construction and arrangement of the parts of which the carriage is composed, endeavor to attain ten principal objects.[1]

1st. Facility of manœuvring the gun, without increasing the size or weight of the carriage, or diminishing its stability.

2d. To render the recoil short, uniform, and easy.

3d. To arrange the breeching in such a manner as to permit the same extent of recoil in every direction, that it shall bring an equal strain on both parts, and produce the least possible reaction.

4th. To increase the safety of the men in time of action.

5th. To increase the train and elevation without increasing the size of the ports; and, if possible, to diminish them.

6th. To secure them in a better manner for bad weather.

7th. To present less surface to the fire of the enemy.

8th. To leave the decks less encumbered and drier than in the present system.

9th. To increase the facility of transportation from port to port, and to render the gun susceptible of service on shore.

10th. To unite all the preceding advantages without increasing the expense; nevertheless, if a carriage could be contrived which should fulfil the preceding conditions better than the present one, it ought to be adopted.

75. The prompt deterioration of wooden gun-car-

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[1] Dupin.—Force Navale de la Grande Bretagne.

riages when exposed to the weather, particularly in tropical climates, induced artillerists to attempt the substitution of iron as a material for their construction. Iron carriages.

These iron carriages are of wrought as well as of cast metal, and the most simple arrangement of the material has been adopted to insure the greatest strength, without an excess of material.

Cast iron carriages are liable to many and serious objections; if the guns they support are also of iron, it frequently happens that with heavy charges they are broken by the shock of the trunnions. This may occur even with a charge of $\frac{1}{3}$ the weight of the ball; consequently we can employ no greater charges than $\frac{1}{4}$. If the battery in which they are placed is exposed to the fire of an enemy, a ball striking them breaks them into numerous pieces, which fly in every direction like grape, and may cause the greatest destruction.

In 1834, experiments were performed at Lafére upon cast and wrought iron carriages, which were found to be unable to resist the impact of even hollow shot; thus the shell of a twenty-four at the first shock broke them into pieces.[1]

76. Among the various carriages which are presented for our consideration, there appear to be but three forms; in one, the body is entirely supported by wheels or trucks; in a second, partly by trucks and a part upon a portion of the body which slides upon the deck; in the third, a bed, or top-carriage, moves upon a slide, which has in general motion around a pivot. Of these forms we will examine six variations. Variations in the form of carriages.

77. We will first review the common gun-carriage, and note its excellencies and defects. It combines strength, stability, simplicity, facility of transportation Common service carriage. Plate II. Fig. 1.

[1] Piobert—Cours d' artillerie, p. 178.

Common service carriage.

on board ship, and capability of being brought up to port again in case of parting the breeching, in a greater degree than any other carriage. Its defects consist in being heavy, cumbersome, and expensive in construction; it recoils violently and unequally upon the breeching, attended by great reaction, which carries it back to the bulwarks with sufficient force to injure the ship; it gets out of the centre of the port, and is with difficulty brought back; it runs out with difficulty and unsteadiness, trains slowly and unsteadily by jerks, which carry it forward or abaft the object aimed at, and has but a limited sweep; the gun cannot be fired until notice is given, and the crew clear of the recoil, during which time the aim may be lost; it does not admit of transportation or service on shore, without a previous preparation of ways and platforms.

Ward's carriage. Plate IV.

78. The modification of Lieutenant Ward obviates some of the objections to this carriage, but introduces some capital defects.

He alters the common service carriage by removing the dumb trucks and bolting a fore and aft piece between the axletrees; introduces a fixed roller handspike, with rollers nine inches in diameter, immediately beneath the trunnions. This carriage is then placed on a slide of such height as to lift the trucks clear of the deck. The ends of the breeching are spliced together, and shackled to a bolt below the centre of the port sill.

The advantages of this arrangement are, convenience of running out, ease of recoil, facility, increase, and steadiness of ordinary train, combined with equal *transportability*, (a want of which is the most common defect of slide-carriages); an equal strain is brought upon both legs of the breeching, the gun is always in

the centre of the port, and the tackles need not be dropped before firing. Ward's carriage.

The defects are, increased room required on deck, and the injury done to it occasioned by the proximity of the slide, which would always keep the main and lower decks of ships wet, and collect filth, and also the weight and expense of the slide. It has not as great extreme train as the common carriage, and to give it greater ordinary train requires a wider breast-piece, or a chock on the slide, to keep the axletrees clear of the water-ways, which lessens the gun's projection from the port, and causes it to occupy more room on deck. The vertical screw, the most convenient arrangement for elevation or depression, cannot be used with this carriage.

79. The Marsilly carriage has superseded all others in the French navy for heavy bomb-cannon mounted in broadside. It differs from the common carriage in suppressing the rear axletree, and extending the cheeks to the deck, upon which they rest, and by their friction check the recoil; running out is facilitated by the use of a roller-handspike placed under the rear of the carriage. Experience has proved this to be the best form of carriage for the bomb-cannon, which are not required to be transported from port to port during action, or, in general, to be established on shore for the attack or defence of a position. Marsilly carriage. Plate V. Fig. 2.

80. The Romme carriage has not been introduced into the United States navy, but the great advantages it combines with the most striking defects entitle it to notice. Its general form is that of the stock trail field-carriage. Its advantages over the common carriage consist in running out easier, recoiling less, greater ease, steadiness, and extent of train, permits a greater number of rounds to be fired in the same time, costs Romme carriage. Plate V. Fig. 1.

Romme carriage.

less, is lighter, being composed of fewer pieces, less liable to get out of order in ordinary service, and can be used with almost equal facility at sea or on shore; it occupies less space on deck, presents less surface to the fire of the enemy, and recoils equally upon the two legs of the breeching. This carriage has two inherent defects, in not giving sufficient elevation for extraordinary cases, and in having a tendency to fall over on its breast in firing to leeward or when the ship is rolling. If we attempt to obviate this last defect by shifting the position of the trunnion-holes, we increase the difficulty of train and running out, and the *crosse*, or part which bears upon the deck, has so much friction as to cut up and destroy it. For these reasons it has been abandoned, although at one period it gave promise of superseding the old carriage.

Columbiad carriage. Plate VI.

81. The arrangement of the late Colonel Bomford for heavy barbette-guns has been adopted, with slight modifications, for the carriages of the heavy ten-inch Columbiads mounted on board several of the bomb-brigs.

The slide does not differ from the one usually adopted for the circle-gun; the top-carriage differs only in the application of a roller-shaft under each end of the carriage, (eccentric with the rollers,) of which there is one on each end revolving independent of the shaft; the end of the shaft is hexagonal, and one man can, by applying a lever, lift either end of the carriage clear of the friction-plates; six men with ease run out or train these pieces weighing fifteen thousand pounds. The carriage is furnished with friction-clamps at the side, to check the recoil, and the breeching is snatched in a crotch in the tail of the cheeks, leaving the breech clear. This arrangement is superior to any other for circle-guns.

82. The Hardy carriage has obtained some reputation, and has been adopted for the light guns mounted on the third class sloops. This carriage is heavy, inconvenient to work, complex, occupies more room than any other species of carriage, cannot be used on shore, nor can it be transported from port to port on board ship without great difficulty; it has every defect of the ordinary carronade-carriage, except its violence of recoil. Hardy carriage.

The carriages which have just been described are undoubtedly the best of their species; all others possess two radical defects, which must prevent their adoption: want of simplicity and transportability.[1] It is probable that the ordinary service-carriage will never be superseded for broadside-guns. All others, to use the words of Preaux,[2] require "the baptism of fire in the presence of an enemy."

83. In connection with the subject of carriages, we shall consider the methods in use for procuring elevation. Pointing in elevation.

First, as most ancient, the common *bed* and *quoin*. This is both inconvenient and dangerous; the elasticity of the carriage usually causes the quoin to jump out of the bed at each fire, endangering the men at the gun, and requiring time to replace it; not unfrequently the bed-rack is made of cast-iron, and is broken by the force of recoil. When rapid changes of elevation are required, it has advantages over any other method; it will also admit of greater extremes of elevation and depression.

84. The *elevating-screw*, which is readily removed Elevating screws.

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[1] For further particulars upon this and other interesting subjects, the reader is referred to the "Experiments on board the Dryade," translated by an officer of the United States navy. Washington.

[2] Connonage à bord, p. 8.

and replaced, has a manifest superiority in its stability and uniformity of motion, and dispensing with the use of the crow and handspike. It is wanting in rapidity of motion; great *changes* of elevation are, however, seldom required at sea.

Screw-quoins.

85. The *horizontal screw-quoin*, as well as the preceding, was introduced by the French. This arrangement has considerable merit; it affords less extent of vertical pointage than either of the preceding, but it admits of more rapid changes of elevation than the last; it must however be admitted, that at sea, after the gun is once laid at the approximate elevation, the rolling of the ship supersedes the necessity of alteration; therefore this advantage is more theoretical than practical. It has not the stability of the vertical screw, and, being out of sight, is liable to become choked with rust. Lieutenant Ward has adopted this quoin in connection with his carriage.

In the heavy Columbiad, or Bomford cannon, the breech is an arc struck from the centre of the trunnion; this arc is divided by notches, into which a steel check is pressed by a spiral spring; the elevation is given by means of a lever placed on the standard against which the spring abuts.

Chocking-quoins.

86. The contrivance called a chocking-quoin, which is at present furnished to all batteries, is conveniently used to prevent the return of the gun to the side, after the recoil when fired, and dispenses with chocking the luff, or placing the crows under the trucks.

CHAPTER IV.

OF GUNPOWDER.[1]

87. Gunpowder is a mixture of nitre, sulphur, and charcoal, in certain proportions. The combustion of gunpowder, and of all compositions in which these substances are the principal ingredients, takes place in successive strata, with a greater or less rapidity, proportionate to the consistence and homogeneity of the mass. Ingredients.

These compositions in the state of fine powder, whether compressed or not, burn with a rapidity determinable by experiment: but the moment the mixture is formed into grains, the circumstances of its combustion are very different, and a detonation or explosion takes place. We will hereafter examine the most important particulars of these phenomena.

88. The proportions of the ingredients of gunpowder have undergone various changes. The oldest known is the following: Nitre, 0.750; Sulphur, 0.125; Charcoal, 0.125. To determine the most advantageous relation of the three components, it is necessary to have recourse to the theory of chemical proportions. Proportions of the ingredients.

89. The proportions should be such that the three

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[1] Vide Timmerhaus, Traité Elémentaire d'Artillerie—Thiroux, p. 316, et seq.—Mordecai on Gunpowder, Braddock and Piobert, Propriétés et effets de poudre.

Proportions of the ingredients.

ingredients may enter into the compound in the chemical proportions necessary to produce, by their mutual combustion, the maximum of heat with the greatest possible quantity of gas. Thus the carbon should be in sufficient quantity to produce, by combination with the oxygen, carbonic acid gas. If the carbon is in excess, we obtain wholly or in part carbonic oxide in lieu of carbonic acid, and the heat developed in this combination will be much less.

In firing a mixture of nitre and carbon, the nitre is at first decomposed; the oxygen of the nitric acid combines with the carbon, and forms either carbonic acid or carbonic oxide gases, depending on the quantity of carbon in the mixture. The potash remains, because heat alone does not decompose it, and it combines with the carbonic acid to form carbonate of potash.

90. If, then, the powder were composed of nitre and charcoal alone, the oxygen contained by the potash would not be liberated to add to the volume of gases; moreover, the potash combines with the carbonic acid, and diminishes the volume still more: but if we add to the mixture a sufficient quantity of sulphur, a complete decomposition of the nitric acid and potash will ensue, and there will be formed from the elements combinations of oxygen and carbon, nitrogen and sulphuret of potassium; the sulphur, having a great affinity for the potassium, will decompose the potash, and this decomposition taking place under the influence of the great affinity of carbon for oxygen, another component of the potash, will be very active, and will cause the development of an intense heat, which elevates the temperature of the gases.

The sulphur then increases, in a definite degree, the two factors of the force of the gases, their density

and temperature, and it is also necessary to add it to the mixture to give the grains the hardness necessary to prevent the absorption of moisture. Proportions of the ingredients.

We have stated that the tension of the gases will be the greatest possible, when the combination of the elements of the powder produces carbonic acid and nitrogen gases, and a residuum of sulphuret of potassium. This, however, supposes that the powder is perfectly dry, and that the combination of its elements, taken in suitable proportions, has been complete. These two conditions never being completely complied with, it follows that the nature of the products of combustion is somewhat modified. We generally find in conjunction with carbonic acid, carbonic oxide, combinations of hydrogen contained in the charcoal, or arising from the decomposition of the acid, with the sulphur and the carbon, and a residuum of carbonate of potash, produced by the combination of a part of the potash, not decomposed, with the carbonic acid.

From the preceding reasoning, it is easy to deduce the proportions of the ingredients of gunpowder; thus, one atom of nitrate of potash, containing six atoms of oxygen, requires three atoms of carbon to form carbonic acid and to free the two atoms of nitrogen which it contains; the atom of potassium requires one atom of sulphur to produce sulphuret of potassium, therefore it follows that the mixture should be composed of one atom of nitrate of potash, three atoms of carbon, and one atom of sulphur, and that the complete combination of these elements will give rise to

GASEOUS PRODUCTS,

Three atoms of carbonic acid,
Two atoms of nitrogen.

Proportions of the ingredients.

SOLID RESIDUUM,

One atom of sulphuret of potassium.

Taking the atomic weights and combining proportions, we obtain the proportions of the three elements, and the powder should contain in 100 parts by weight:

74.639 of nitre,
13.509 of carbon,
11.852 of sulphur.

92. It is necessary to remark, that charcoal contains alkaline salts, constituting the ashes which are the residuum of combustion, and a quantity of hydrogen, which can only be driven off by the application of an intense heat—finally, if the wood from which it has been obtained was not exposed to a very elevated temperature, it still contains a quantity of undecomposed vegetable fibre, which contains much ulmic acid. It follows that to obtain 13.509 parts of carbon in the mixture, we must take a larger proportion of charcoal. Our own proportions, 76—14—10, and the English proportions, 75—15—10, appear to satisfy all the conditions required.

From the results of experiments made to determine the volume of the gases produced by various proportions of the ingredients, we find that within the limits of 6 : 1 : 1, the greatest quantity of gas of the greatest elastic force is produced; other proportions produce a greater quantity of gas, but since there is less carbonic acid, the combustion is incomplete, and the temperature less elevated: the ordinary variations in the proportions have no appreciable influence on the strength of powder.

Inflammation of gunpowder.

93. Gunpowder when inflamed is speedily resolved into gases, which by their great tension and elastic

force, have a tendency to occupy a space many times greater than that occupied by the charge; but finding an irresistible obstacle to their expansion in the sides of the bore, most of the products of combustion escape by the muzzle in the form of a very rapid current, driving before them with great violence the projectile which opposes their motion.

Temperature of inflammation.

94. This inflammation takes place at about 600° (Fahrenheit), the principal products of combustion being, as before stated, carbonic acid, carbonic oxide, and nitrogen gases, and sulphuret of potassium. The latter being probably in a state of vapor, increases the tension in a more rapid progression than the gases, as the temperature is raised, and ought to play a very important part in the first moments of the combustion of the powder, when it completely fulfils its destined office.[1]

The elevation of temperature due to this phenomenon, is valued by Piobert[2] at 2400° (Cent.), and the tension of the gases at 7500 times the atmospheric pressure.

Period of its invention.

95. The invention of gunpowder is generally attributed to Roger Bacon, an English monk, who flourished in the beginning of the 13th century. The Chinese claim a knowledge of its effects prior to the Christian era, and this claim would seem to be sustained by the fact that the great wall, now 2000 years old, is pierced with embrasures for cannon.[3]

Be this as it may, its use has been gradually extended, and we may affirm that its adoption has ameliorated and completely changed the political, moral, and social relations of the human race.

Explanation of its mode of action.

96. The action of gunpowder is easily explained. The gases produced by the combustion of the charge,

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[1] Thiroux, p. 288. [2] Cours d'Artillerie, p. 19, 21.

[3] Fauvé Histoire d'Artillerie.

confined in a small space, are forcibly expanded by the excessive heat disengaged by the combustion, and in their endeavor to escape, exert against the projectile in the bore of the gun a pressure and percussions which impress upon it a great velocity.

Useful effect produced.

97. The effect produced depends principally on the purity and proportions of the ingredients, on their manipulation, the velocity of combustion of the powder, and the resistance to be overcome.

Qualities requisite.

98. Good powder should satisfy three principal conditions, that is—1st. To preserve its qualities in magazines and in transportation. 2d. Not to be too injurious to the arm for which it is destined. 3d. To produce its useful effects regularly, and the greatest possible while fulfilling the second condition.

MANUFACTURE OF GUNPOWDER.

99. Gunpowder is never employed in the state of a simple mixture of the ingredients reduced to a fine powder, but the mixture is always formed into grains, either round or angular. By this we obtain several advantages, which may be explained in a few words.

Advantages of graining.

1st. Grained powder permits the flame to penetrate the mass more easily through the interstices of the grains; a simple mixture, although compressed, also leaves interstices between the particles, but they are not of sufficient size to permit the free passage of the flame, consequently the inflammation can only be communicated to the mass stratum by stratum, as it takes place, though much less rapidly, in the combustion of portfires, which are composed of the same ingredients as gunpowder, but in a slightly different proportion.

2d. The powder when grained does not sift through the cartridge bags or between the staves of the barrels;

the transportation of the powder and its employment become less dangerous in consequence of its graining. Advantages of graining.

3d. Grained powder does not absorb moisture as readily as a simple mixture.

4th. Each portion of the mass preserves the requisite proportions of the three ingredients in a better manner.

In a simple mixture the proportion will be constantly destroyed by motion: the different strata of powder in a barrel would evidently arrange themselves in the order of their densities, consequently the lower strata would contain the denser ingredients in excess, and the contrary with the others.

The granulation of gunpowder requires that the materials should be so compact that it can only be performed by permitting the mixture to retain a certain degree of moisture (which must be proportionally greater as the compression of the mass has been less), which it is afterwards necessary to drive *off*. The drying produces a dust which must be removed by sifting.

100. The manufacture of gunpowder then requires the performance of the following operations:

1st. The pulverization of the ingredients.

2d. Their incorporation and compression into a compact mass.

3d. The granulation of the mass.

4th. Drying the grains.

5th. The separation of the dust from the grains, or sifting.

In most countries glazing is added to the preceding operations (sporting powder is always glazed); this offers an excellent means of varying, by diminishing the rapidity of combustion of the powder; a means,

the more advantageous since glazed powders are more easily preserved than others.

Pulverization of the ingredients.

101. Formerly the pulverization of the ingredients and their incorporation were performed at the same time in the pounding mills. These mills contained a number of mortars dug out of blocks of hard wood, into which a pestle, the lower part of which was made of bronze or very hard wood, fell with a rapidity dependent on the charge. This process was dangerous, and in addition the pulverization of the sulphur and nitre was not complete, particularly the first, which, when mixed with other substances, is with difficulty reduced.

At present, in pounding mills, the materials are pulverized separately, and mixed either under the pestles or in rolling barrels.

These rolling barrels, which are about 44 inches in diameter and 22 inches long on the interior, are made of strong leather or hides stretched over a frame. Each barrel contains about 100 pounds of zinc balls about .25 of an inch in diameter, and a charge of composition half the weight of the balls; the barrel is caused to revolve 25 or 30 times in a minute.

Cylinder mills are now in general use in this country, and perform at the same time the operations of pulverizing, incorporating and pressing the composition. They consist of two cylinders of marble or cast iron weighing about 5 tons each, rolling in a circular trough of the same material, the inner diameter of which is about three feet; a wooden plough follows the cylinders, to bring the composition towards the centre of the trough.

The incorporation of the ingredients and compression of the mass.

102. The materials having been mixed in the required proportions, are placed under the pestles of the pounding mill, or spread in a thin layer in the trough of a cylinder mill. In the first the incorporation is performed by fifty-five strokes of the pestles in a minute, continued 11 hours. In the cylinder mills the rollers revolve 10 times in a minute, and run from one to three hours on each charge of 50 pounds.

Under the rollers the composition becomes of sufficient density, but the powder incorporated in the pounding mill, is subjected to pressure by an hydraulic or screw press until it has attained the required density.

The granulation of the mass.

103. The composition being formed into *cake* by either of the preceding methods, the next process is to break it up into grains; to facilitate this, it is partially dried; it is then put into a graining sieve, formed of parchment pierced with holes, where it is broken up by the action of a lenticular disk of hard wood; the sieve is shaken either by hand or machinery in such a manner as to cause the disk to move round it against the border, and the grains pass through the holes as fast as they are sufficiently reduced. Another method of graining is to pass the cake through toothed rollers. The grains thus formed are sifted to separate from each other the different kinds of grains for *cannon*, *musket* or *rifle* powder. The influence of the size of grain is hereafter discussed.

The glazing.

104. Glazing is necessary in order to enable gunpowder to resist the effect of shaking in transportation and of exposure to humidity. This operation is performed by inclosing the powder containing about 3 per cent. of moisture, in a large glazing barrel, which is caused to revolve on a horizontal axis. The velocity of the glazing barrel is at first very little; the action of the grains against each other and the sides and ledges of the barrel is slight and the density of the grain slowly increases; the rate is then accelerated, and towards the end of the operation again diminished; this last decrease of velocity is for the purpose of cooling the grains, for if we withdraw the powder from the glazing barrel while it is in a heated state, it loses a part of its fine lustre and becomes friable.

Glazing renders the grain denser, and this density becomes greater as it contains more moisture; the abrasion of the grains against one another, and against the inner surface of the barrel, breaks off the sharp points and angles, imparts to them more roundness, and finishes by adding a smoothness and polish to their surface.

The protection which glazing offers against the absorption of humidity is very important; the moisture absorbed by gunpowder is the principal cause of the damage which it sustains, and we cannot deprive it of this moisture without leaving it still more liable to injury, and without altering its combustibility. If, on the contrary, the moisture is not driven off, then it is evident that the combustibility and useful effect of the powder will be greatly diminished, on account of the great quantity of heat rendered latent in the vaporization of the moisture.

The effects of glazing upon the inflammation and combustibility of the grains will be considered in Art. 133.

Drying the grains.

105. After granulation the powder contains more or less moisture, which was necessary to effect that operation, and it becomes necessary to remove it by the application of heat. The drying may be effected in two ways: 1st, in the open air; the powder is spread upon sheets, laid on tables in a suitable situation, where it remains ten or twelve hours, being frequently stirred to expose it thoroughly to the sun; in summer it requires to be sometimes covered, in the heat of the day, to prevent the loss of the sulphur. 2dly, in a drying house, where the powder is exposed in layers, from one to four inches thick, to a current of air, heated to about 140° by means of a furnace or steam pipes.

It is highly important that the drying should affect the solidity of the grains as little as possible, and that its porosity should not be sensibly increased, for a powder with a porous grain, of little consistency, will evidently absorb moisture, which is the principal cause of the damage which it sustains.

The drying often destroys the effects obtained by glazing, by rendering the grain again porous and depriving it of its lustre: this happens oftener when the grain is large; the quantity of moisture which it contains is considerable, and the drying is most rapid.

To avoid these inconveniences, it is necessary that the drying shall take place at a temperature which is at first not too elevated; for the steam formed in the interior of the grain will open larger passages for its escape as its tension, which increases rapidly with its temperature, is greater, and as the resistance offered

by the surface of the grain too soon dried and hardened is greater.

It has been proposed to raise the powder to a temperature of 500°, for the purpose of fusing the nitre and sulphur, and placing it beyond the reach of the ordinary humidity of the atmosphere; this dangerous experiment has not been made for service powder. Damaged gunpowder, if not too much injured, may be made serviceable by re-drying it and separating the dust. It should first be passed through a sieve, to break the lumps and separate extraneous matter.

The separation of the dust from the grains.

106. After the powder has been glazed and dried, it is sifted, in order to remove the dust. The dust and small grains obtained in this and the previous operations are again pressed or worked over to make inferior powder, or mixed with a portion of fresh composition. Gunpowder made from this re-worked dust, or meal powder, gains no strength by this additional incorporation; on the contrary, it is not so strong, nor so regular in its effects, as powder which is made from fresh ingredients. This is, perhaps, due to a greater proportionate loss of charcoal, the most volatile of the ingredients, and the most likely to fly off and be lost in the several stages of the manufacture. This would appear to confirm the opinion expressed in Art. 123, that there is a certain point at which the process of incorporation has attained its maximum, and beyond which the powder receives no increase of strength.

Other modes of manufacturing gunpowder.

107. *Round powder* may be made in an expeditious manner, as follows: Fix a powder-barrel on a shaft

passing through its heads, the barrel having ledges on its inside; to prevent leakages, cover it with close canvas glued on, and put the hoops over the canvas. Put into the barrel 10 lbs. of sulphur in lumps, and 10 lbs. of charcoal, with 60 lbs. of zinc balls, or of small shot; turn it, by hand or otherwise, thirty revolutions in a minute, until pulverized; to 10 lbs. of this mixture thus pulverized, add 30 lbs. of nitre, and work it two hours with the balls; water the 40 lbs. of composition with two quarts of rain-water, mixing it equally with the hands, and granulate it with a sieve. The grains thus made are too soft; to make them harder, put them into a barrel having five or six ledges projecting about 0.4 in. inside; give it at first eight revolutions in a minute, increasing gradually to twenty. The compression will be proportionate to the charge in the barrel, which should not, however, be more than half full; strike on the staves of the barrel, from time to time, to prevent the adhesion of the powder.

Sift the grains, and dry the powder as usual; that which is too fine or too coarse, is returned to the pulverizing barrel.

This powder is round, and the grain is sufficiently hard on the surface, but the interior is soft, which makes it unfit for keeping.

It appears, from experiment, that a simple mixture of the materials gives ranges about three-fourths of those given by grained powder; the incorporated dust from the rolling barrel may therefore be used in case of necessity.

The preceding sketch of the mode of manufacturing gunpowder, is all that comes within the scope of

this treatise; for a complete dissertation, the reader is referred to the treatises upon that subject.

We will proceed to examine the conditions under which the combustion of gunpowder takes place, and the measure of its useful effects.

ON THE COMBUSTION OF GUNPOWDER.

Preliminary ideas.

108. The inflammation of gunpowder, the taking fire of all the mass, should be carefully distinguished from its combustion, or change of state from a solid to a gaseous form.

The velocity of inflammation is so great, that it is almost impossible to ascertain its duration, at least when nothing opposes the free circulation of the flame through the powder; the combustion, on the contrary, requires a definite interval of time, and for ordinary charges is not completed until after the displacement of the projectile, and during its passage along the bore of the gun.

109. Of the three elements of which gunpowder is composed, the sulphur is the most inflammable. We can fuse it, and even inflame it (which takes place at 270° Fahrenheit), without exploding the powder of which it forms a part; but to do this, it is necessary that the temperature shall be slowly raised to the proper point, by the gradual application of heat.

With a spark, produced by the collision of a flint and steel, we do not succeed in inflaming the sulphur, and if we communicate the fire to the powder by this means, it is not the sulphur, but the charcoal, which first takes fire.

110. The complete inflammation of gunpowder re-

quires that a part of its mass shall be raised to a red heat, or about 600°. We may convince ourselves of this fact, by burning hydrogen gas in an eprouvette, in presence of the powder, which will not take fire, or by placing a small quantity of powder in contact with the flame of blazing paper, which, if quickly withdrawn, will not inflame it. Preliminary ideas.

111. The inflammation may be caused by a spark, or any other cause which suddenly or gradually raises its temperature to the necessary degree.

According to various authors, powder explodes by the collision of iron against iron, iron upon brass, brass against brass, and less readily by copper against copper. By experiments made in England, it also explodes by the shock of bronze and copper, iron and marble, quartz and quartz, lead and lead, or when a leaden ball was fired against a pendulum sprinkled with powder; finally, by contact with live coals, jets of gas, &c.

112. Powder brought in contact with a body in an incandescent state, takes fire at once, and explodes; thus, in guns, the flint striking against the face of the battery, tears off small particles of steel in a state of incandescence, which soon communicate fire to the priming.

We can, therefore, produce the inflammation of the powder in a certain and rapid manner: 1st. By contact with incandescent charcoal, as with the ordinary match; 2d. By the flame which accompanies the combustion of a mixture similar to that of gunpowder; 3d. By a priming of fulminating powder. This last method appears to be, above all others, the most proper to attain the object. Their flame penetrates the mass with the greatest rapidity, almost instantaneously envelopes the grains, and communi-

Preliminary ideas.

cates to them the high temperature which is necessary to induce their inflammation.

113. Opinion has long been divided as to the time necessary for the combustion of gunpowder. Robins considered it instantaneous, or at least so rapid that it might be so considered; Belidor, on the contrary, shows that the combustion is successive. This opinion, which is based on the simple consideration that the flame, whatever may be its rapidity, requires a certain time to penetrate the mass of the charge, and the interior of the grains themselves, is placed beyond doubt, by experiments which it is unnecessary to cite.

These experiments prove, that powder is consumed more rapidly, in a space partly closed, than in the open air; and that in guns, where the flaming gases have no other mode of escaping than between the projectile and the sides of the bore, or by driving the projectile before them, the combustion is of an extraordinary rapidity.

It is, however, certain that the combustion of gunpowder in guns is not only successive, but that even its inflammation need not be rigorously considered as instantaneous.

114. The law by which the initial velocity of the projectile varies as a function of the length of the bore, is an incontestable proof that the combustion of gunpowder is not instantaneous, and that it is, at least for ordinary charges, much slower than is generally imagined. For, if all the powder was consumed before the displacement of the projectile, the elastic force of the gaseous products at any point of the bore, taking into consideration the decrease of temperature according to the law of Mariotte, would be in the inverse ratio of its distance from the bottom of the

bore. If we also allow for the heat absorbed by the surface of the bore, it is evident that the real decrease of the accelerating force should be still more rapid. It follows, that if we consider the accelerating forces at any two points of the bore in an inverse ratio less than that of their distances from the bottom, we must admit that the combustion of the powder is not entirely finished, and that the loss of the elastic force of the gases due to their extension into a greater space, is in part compensated by the evolution of a new quantity of gas. Experiments made to determine this point, prove that the decrease of the accelerating force *is* much less rapid than if, at any distance from the bottom of the bore, the combustion of the powder was complete; hence, we may conclude that the combustion is not finished before the projectile leaves the gun, or a short time previous. The initial velocity of the projectile is, therefore, proportional to a certain root of the length of bore; or, $v = l^{\frac{1}{x}}$, v being the initial velocity of the projectile, l the length of bore; the exponent $\frac{1}{x}$ varies with the combustibility of the powder, the ratio of the charge, and probably with other circumstances which have not been, as yet, well determined. For ordinary powders and medium charges, the velocities vary as the fourth roots of the length of bore.

Preliminary ideas.

115. Recent experiments, which have been made upon large grains and prisms of powder, to determine the law by which it inflames, show that the combustion takes place by strata of equal thickness; and

1*st*. That the velocity with which the fire is transmitted, is the same throughout the whole extent of the prism.

2*d*. That equal quantities are consumed in equal times.

Preliminary ideas.

3*d*. The velocity with which the combustion is transmitted, is independent of the surface.

4*th*. That the density, the manipulation, and the quality of the ingredients, exercise great influence upon the velocity of combustion.

5*th*. The velocity of combustion diminishes as the density is increased, in the inverse ratio of the density.

6*th*. The porosity of the powder sensibly modifies the velocity of combustion. Powder caked by moisture, and afterwards dried, often gave a triple velocity of combustion, on account of the facility with which the flame penetrated the interior of the grains.[1]

116. The velocity of combustion, therefore, depends

1*st*. On the temperature of the gases, which determines their velocity and tension.

2*d*. On the facility with which the inflamed gases penetrate the mass.

3*d*. On the facility with which the grains take fire.

4*th*. On the combustibility of the grains.

117. The temperature of the gases, and therefore their velocity, is principally determined by

a. The purity of the ingredients.

b. Their proportions.

c. Their mode of incorporation.

d. The dryness of the powder.

e. The ratio of the charge.

f. The resistance to be overcome.

g. The extent and form of the place in which the combustion takes place.

h. The windage and size of the vent.

i. The place where fire is communicated to the charge.

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[1] This explains why very dense powderi s often improved by being dried after exposure to humidity.

j. The species of priming employed. Preliminary ideas.

k. The material of which the gun is composed.

l. The temperature of the gun.

118. The penetration of the gases through the mass, depends on the number and size of the channels in the interior of the mass: if these channels are formed by the interstices between the grains, they are determined by

a. The size of the grain.

b. Its form.

c. Its equality.

d. Its freedom from dust.

119. The facility with which the grains take fire depends

a. On the extent of their surface.

b. On the glazing.

c. On the shape of the grains.

d. On their density.

e. On their freedom from dust.

120. The combustibility of the grains is determined by

a. The size of the grain.

b. Its density.

c. The intensity of the heat developed.

We will now proceed to examine the influence of these different causes upon the combustion, first considering those which modify the temperature and tension of the gases.

Of the purity of the ingredients.

121. The combustibility of gunpowder is intimately dependent upon the purity of the ingredients of which it is composed; if the nitre is impure and con-

Purity of the ingredients.

tains a large proportion of chlorides, the quantity of free oxygen will be less, and the combustion less active; the chlorides have also the disadvantage of attracting moisture, which disintegrates the powder and renders it less quick. The charcoal becomes a good or bad conductor of heat, depending upon the temperature to which it has been raised, and exercises a great influence upon the rapidity of combustion.

Thus, although we may easily raise the temperature of a particle to the degree necessary to cause its inflammation, this becomes less easy when this particle communicates to those adjacent a portion of the heat received. For, in this case, the temperature of these last must also be raised to the degree necessary to induce combustion.

Charcoal slightly calcined contains the most hydrogen, and it is this gas which developes the most intense heat during its combustion. Finally the sulphur accelerates the combustion by its affinity for the potassium, and because it inflames at a low temperature; the foreign bodies which it contains must necessarily weaken this property of the sulphur.

According to Mordecai, p. 276, the nitre may contain a considerable proportion of foreign salts without sensibly affecting the strength of powder when it is new, or has been well preserved for a moderate period of time. Braddock, p. 8, says, "they are noxious only inasmuch as possessing no particularly useful property, they interpose their atoms between the more combustible ingredients, and impede the rapidity of deflagration;" their deliquescent properties would, however, be highly injurious, as they would cause the powder to absorb moisture greedily.

Of the proportions of the ingredients.

122. In speaking of the proportions, we have already designated those which give the greatest quantity of gas of the greatest possible elastic force; by changing the proportions, we evidently vary the nature of the products of combustion, and the quantity of heat developed, and the rapidity of combustion will necessarily be modified. Thus an excess of charcoal occasions the formation of carbonic oxide, and too little sulphur produces a residuum of carbonate of potash.

The variation in the chemical combinations, varies the heat developed, and with it the velocity with which the powder is consumed.

Mordecai, p. 322, says, "The proportions used in making our best powder, 76, 14, 10, and the English proportions, 75, 15, 10, appear to be favorable to the strength of powder, and not sensibly disadvantageous in other respects; but the ordinary variations in the proportions of cannon powder are scarcely appreciable by their effects on its force."

Of the mode of incorporation.

123. The degree of division and the intimacy with which the ingredients are mixed, influences in a great degree the combustibility of the powder; the nature and force of compression modify the density of the grains, the influence of which upon the velocity of combustion is very great. Braddock asserts that "perfect manipulation will produce a stronger and better powder with bad proportions, than imperfect manipulation will produce with good. When gunpowder is

Of the mode of incorporation.

used in large quantities in heavy ordnance, its effects are more dependent on circumstances connected with its manufacture, than on the accurate adjustment of its primary elements."

The method of manufacturing powder in use in this country (in cylinder mills) produces a well incorporated powder, but of great density. This powder strains the gun less than less dense and consequently quicker powder, while it produces the maximum of useful effect. An undue density, however, lessens the combustibility, and renders it more liable to injury from exposure to moisture.

Of the dryness of the powder.

124. This increases the rapidity of combustion in a great degree. Thus, we may easily conceive that the vaporization of the water absorbs a great quantity of heat, which remains latent, diminishes the temperature of the gases and consequently their tension. The humidity also occasions agglomerations of the grains, which do not leave sufficient channels for the free passage of the inflamed gases; finally, it causes an efflorescence of the nitre on the surface of the grains, forming a crust which inflames with difficulty.

On this point, Braddock says, "Humidity and dryness are well known to exert a great and opposite influence on gunpowder; and when it is heated by artificial means, and fired while it possesses a high temperature, the range is amazingly increased." By adopting this suggestion, damaged powder, or an insufficient quantity, may be made to produce an effect equal to the service charge.

Of the ratio of the charge.

125. The heat developed increases with the charge, and, as the velocity of the gases increases with their temperature, it is therefore evident that a heavy charge is consumed proportionally quicker than a small one; it is also true, that the loss of heat absorbed by the surface of the bore is much less sensible when the charge is great than when it is small; that is, the quantity absorbed is proportional to the surface, or the square of the calibre of the gun, whilst the heat developed increases as the cube of the calibre.

Finally, several properties of powder which accelerate combustion, have no effect when the charge is very small: thus, for example, the influence of the size and shape of the grain, which determine the free circulation of the flame through the mass, does not come in play when the charge is small, which, whatever may be the granulation of the powder, is almost instantaneously enveloped in flame.

The influence of the ratio of the charge upon the duration of the combustion appears to be very great; for a multitude of causes which may vary the time when the charge is small, appear to be neutralized and become imperceptible when it is large.

Of the resistance to be overcome.

126. When the projectile offers a great resistance, it is not so quickly displaced as when the resistance is slight; its motion in the first instance is then less rapid, and it evidently follows, that the combustion takes place in a space more confined as the resistance to be overcome is greater.

For, the smaller this space is, the more the heat is

concentrated, the higher the temperature of the gases is raised, and consequently their velocity is increased, the inflamed gases have a less distance to expand through, and there follows from all these causes a train of circumstances, all of which accelerate the combustion of the charge, and consequently sensibly shorten the duration of the combustion.

Of the extent and form of the place in which the combustion takes place.

127. That the combustion of the powder, all other things being equal, shall be quickest possible, it is necessary that the charge shall completely fill the chamber or part of the bore which it occupies, and that the surface of the chamber shall be a minimum. For, the more confined the space in which the combustion takes place, the greater will be the concentration of heat; and if in addition, the surface containing it is a minimum, the absorption of heat by that surface will be least, the combustion will be completed under the highest possible temperature, so that it will be as quick as the other circumstances will permit.

If the size of the chamber is such that a vacuum exists between the charge and the projectile, this circumstance is evidently disadvantageous, for the combustion taking place in a space greater than that occupied by the charge, will be at a less elevated temperature.

The dimensions of the place in which the combustion is effected have such an influence on its rapidity, that they often neutralize the great effects resulting from a low density of the grain, since this want of density renders the mass less dense, and consequently the charge occupies a greater space.

Piobert, from the results of experiments made at Esquerdes, deduces the conclusion, that by interposing some elastic substance between the charge and projectile—that is, by increasing the space in the rear of the ball—we can render quick powder less destructive to the gun than slow powder, with the ordinary manner of loading; and this conclusion is in accordance with the considerations already mentioned. This interposition of an elastic body not being practicable, it has been proposed to place the powder in cylinders of increased length and diminished diameter, which leave a vacant space between the powder and upper part of the bore; this permits an expansion of the gases formed in the first instants, before the projectile is displaced, reduces the strain on the gun, and at the same time increases the velocity of the projectile. Extent and form of chamber.

Various experiments have been made to determine the effect of the containing surface upon the velocity of combustion; but, as these experiments were made upon trains of powder in grooves, with one surface exposed to the air, the deduction that the times of combustion are as the containing surfaces does not appear to be rigorously correct. To deduce rigorously the ratio of the containing surface to the time of combustion of two equivalent trains of equal length, it would be necessary to confine them in tubes of different form and surface, but of equal capacity.

Whatever this ratio may be, we can deduce from these experiments the conclusion that the increase of containing surface is injurious to the vivacity of combustion.

Of the windage and diameter of the vent.

128. The greater the windage and the diameter of the vent, the greater will be the loss of gas in the first

instants, without useful effect, and this loss will be relatively greater as the powder is slower; from this follows a decrease of temperature and a loss of inflamed gas, which disadvantageously influences the velocity of combustion of the remainder of the charge.

Of the place where fire is communicated to the charge.

129. When a quantity of powder is contained in an inclosed space, all the sides of which offer an equal resistance, it is evident that the inflammation and complete combustion will be the quickest possible when the fire is applied to the centre of the charge.

In cannon, the force developed does not meet with the same resistance in all directions: the projectile yields as soon as a sufficient force acts upon it; and as the combustion of gunpowder is much slower than is generally supposed, it follows that a great part of the charge is not consumed until after the displacement of the projectile. The combustion is completed in a space much greater than that occupied by the charge, and the tension and velocity of the gases will be much less; besides, the unconsumed grains are mingled with the current of gas already developed, and driven forward from the place where the heat is most intense; and it necessarily follows that the complete combustion of the charge is retarded: therefore, it appears to be evident, that the combustion will be more rapid in proportion as the displacement of the projectile is slower, and that it will reach its maximum velocity when the space in which the complete combustion takes place shall be a minimum.

130. The position of the vent may influence the time required to displace the projectile. Thus, for example, with the regulated vent, it is the upper part

of the charge, that which is in contact with the interior orifice of the vent, which first takes fire; the inflammation is communicated to the parts adjacent, and promptly reaches the projectile; the inflamed gases endeavoring to escape above this last displace it; it follows that, in this position of the vent, the space in which the combustion takes place increases from the first, and that it is completed in a space much greater than that at first occupied by the charge. If the vent is pierced in the direction of the axis, its interior orifice is at the centre of the bottom of the charge, and the inflamed gases do not come into immediate contact with the projectile until after the complete combustion of the charge has taken place. The projectile cannot take up motion until this occurs, unless motion is communicated to it by the unconsumed powder still interposed between it and the gases already developed:—but this transmission requires a certain time; and it is probable that the combustion will be so rapid that the displacement of the projectile will be scarcely sensible before the combustion of that part of the charge in contact with it.

Of the place where fire is communicated to the charge.

131. This explanation being admitted, it appears probable that the direction of the vent which produces the most rapid combustion ought to terminate at the centre of the bottom of the charge.

Experiments made in France in 1830, in the schools of artillery at Douay, Strasbourg, and Toulouse, have established the truth of this opinion. These experiments were made at each school, as nearly as possible under the same circumstances, with three guns of the same calibre, in which the vents were pierced: for the first, in the prolongation of the axis of the gun; for the second, in a line inclined 30° to the axis; for the third, in the ordinary position (at an angle of 70° with the axis).

Of the place where fire is communicated to the charge.

The results of these experiments were: 1st. That the ordinary position of the vent produced the least recoil, and that it had also an advantage over the other two positions with respect to range and accuracy of fire. 2d. That this position did not cause a sensible alteration in the gun, whilst the enlargements of the bore were greater than two lines in those guns in which the vent was in the axis, or formed an angle of 30° with that axis.

The great indentations which have been observed in the pieces with the vent in the axis, or inclined to it at an angle of 30°, can only be explained by supposing a more rapid combustion of the powder in the first than in the second; for those injuries, which are due to the expansive action of the gases, ought necessarily to increase with the tension of these last.

Of the species of priming employed.

132. The force, and particularly the velocity with which the flames of percussion powder penetrate a charge, are incomparably greater than those of the gases produced from gunpowder. A greater part of the charge is inflamed in the first instants, and the rapidity with which the whole charge is consumed should be considerably increased.

The experiments made by Major Mordecai, however, show that the use of percussion primers for cannon does not produce a sensible increase of velocity: for small arms their use is advantageous.

Of the material of which the gun is composed.

133. The qualities of the gun, as a good or bad conductor of heat, lower more or less the temperature of

the gases, and differently retard the duration of combustion. It is shown by experiment, that iron guns give longer ranges than those of bronze; probably because bronze is a better conductor of heat.

Of the temperature of the gun.

134. If the gun had the same temperature as the gases, it would not deprive them of any part of their caloric. As the difference between the temperature of the metal and the gases increases, the quantity of caloric absorbed by the gun will increase, and the temperature which accompanies combustion be lowered more promptly.

The density of the atmosphere and the temperature of the surrounding air, may exercise some influence upon the rapidity of combustion, but it must be slight.

We will now point out the physical properties of the grains which may modify the penetration of the flame through the mass, and into the grains.

Of the size and form of the grain.

135. We have already stated that the granulation of gunpowder renders its combustion more rapid, because it permits the free circulation of the flames through the mass, which they almost instantaneously penetrate. If the powder is not grained, and, in consequence, the interstices between its particles are small, the flame can only penetrate the mass little by little, and the combustion ensues in successive strata. We

Of the size and form of grain.

see examples of this in port-fires, which, notwithstanding their quick composition, burn from five to ten minutes; in rockets, which raise themselves to a considerable height before the combustion is finished; or in the fuse of a shell, which burns long enough to permit it to reach the target before it communicates fire to the charge which it contains.

Tubes would also burn slowly if they were solid: their rapid combustion is due to the channel in the interior, which presents a great surface at the same time to the action of the flame.

The form and size of the grains modify,

1st. The extent and the regularity of the interstices which these last leave between themselves.

2d. The surface which the grains present to the flame.

3d. The density of the mass of powder.

The size and regularity of the interstices determine the greater or less difficulty of the passage of the flame, which communicates the inflammation to the mass in the direct ratio of the surface of the grains which it encounters.

The greater or less density of the mass concentrates the combustion in a more or less confined space, and therefore influences the temperature and density of the gases and the loss of caloric absorbed by the sides of the bore: thence it follows, that the form and size of the grain should exert a great influence upon the velocity of combustion.

136. The form of the grain is either angular or spherical, and is partly determined by the diameter of the holes in the graining sieve. Each of these forms, spherical or angular, gives the grain certain properties, some of which are favorable, others injurious, to the rapidity of combustion. The surface of grained powder and

the density of its mass is, for equal size of grain, greater in angular powder than in round powder. These two circumstances favor the rapidity of inflammation : the sudden checks received by the flame cause it to surround the grain, whilst it is more or less reflected from the glazed and curved surface of round powder. On the contrary, angular powder leaves irregular interstices, and it follows, whenever its grain is unequal, that a part of these interstices are filled with smaller grains. This clogs the free circulation of the flame in so great a degree as to more than compensate for the disadvantages of round powder, which, by the regularity of its interstices, offers fewer anomalies in its effects, to which great advantage is added greater facility of preservation.

Of the size and form of grain.

137. The surface of any powder increases in the inverse ratio of the size of grain; therefore it may often occur that a round powder, if its grain is sufficiently small, may present a greater surface than angular powder, the grain of which is large.

Of the equality of grain, and its freedom from dust.

138. When the grain is unequal, the smaller grains interposing themselves between the larger impede the free circulation of the flame through the mass. The retardation which this occasions in the inflammation of the mass is rendered still greater when the powder contains dust. The small grains being consumed first, develope sufficient force to displace the projectile, and the combustion of a great part of the charge is completed in a proportionally greater space, and slower, as the tension of the gases is less.

Of the influence of glazing.

139. The glazing of the grains facilitates the rapid transmission of the flame through the mass; but it impedes the penetration of the inflamed gases into the interior of the grains, and considerably diminishes their combustibility. This last effect is readily explained. First, because their polished surfaces, the pores of which are partly stopped up, reflect the inflamed gases, and do not permit them to act readily; in the second place, because the greater density of the grains which have been glazed renders the penetration of the gases into the interior of the grains more difficult.

When the quantity of powder is small, and in consequence the flame is transmitted with facility through the whole mass, glazed powder should be slower than that which is rough; but when the charge is heavy, the rapid penetration of the gases through the mass, so that the whole is completely inflamed before the displacement of the resistance, may shorten the total duration of the combustion, and the whole be consumed in less time than an equal quantity of rough powder.

In the eprouvette, glazed powder has a marked disadvantage. In cannon, on the contrary, particularly those of heavy calibre, glazed powder is always superior.

Of the density of the grain.

140. The velocity with which a charge of powder is consumed depends, as has been already stated, on the combustibility of a single grain, and the facility with which the flames penetrate the whole mass.

Round powder facilitates in a great degree the

transmission of the flame, and this is more evident (because the size of the interstices increases) as the grain is greater. If, in addition, each grain possesses a great degree of combustibility, it is also evident that round powder in large grains will be highly combustible.

Of the density of the grain.

But the combustibility of the grain depends, first, on the extent and nature of its surface; and, in the second place, on its porosity. If this last is so great that we may consider the grain as an agglomeration of smaller grains, leaving between themselves pores sufficiently great to permit the flame to easily penetrate to the centre of the grain, it is evident that its deflagration will be as rapid as possible.

When the density and hardness of the grain is carried to excess, the powder is inflamed with difficulty, and gives much shorter ranges than those given by service powder of good quality. The porosity of the grain is singularly favorable to its combustion. In the course of some experiments with very porous powder, a four-pounder was burst with a charge much less than is required to produce the same effect with the powder in common use.

It therefore follows that the density and hardness of the grain should exercise great influence upon the rapidity of combustion. Experiment fully confirms what the preceding reasoning has endeavored to establish.

THE EFFECT OF GUNPOWDER IN CANNON, AND ITS VALUATION.

Preliminary ideas.

141. The force acting upon the projectile and the gun, consists in the impulse and pressure of the gases disengaged by the combustion of the charge, the tension of which is proportionally greater as they are more strongly compressed, and their temperature elevated.

It is difficult, if not impossible, to determine accurately the nature of the gases developed, their respective quantities, their volume under a given pressure, and, above all, their temperature. In fact, all these factors of the motive force are essentially dependent on a more or less complete combination of the components of the powder—a combination which varies with the ratio of the charge, the species of gun, the resistance to be overcome, and with a great number of other elements which are not constant from one gun to another, or even in the same gun. It follows that the intensity of the motive force of the gases is not absolute, but, on the contrary, that it is essentially relative.

To appreciate the value of each of these different factors of the motive force of the charge, it would be necessary for us to know the conditions under which the combustion takes place in the gun; it would also be necessary to collect the products of combustion, and, above all, to have some means of valuing the excessive heat which accompanies the combustion.

The motive force of the gases developed depends on their volume under a given pressure, and on their temperature; we can calculate in a sufficiently accurate manner the volume of the gases, but we have no means

of valuing their temperature, and on this subject must have recourse to a more or less probable hypothesis. Preliminary ideas.

142. The action of the gases upon the projectile does not appear to be similar to a pressure, but is rather to be considered as a series of impulses, or shocks; for, these gases being possessed of a greater velocity than the projectile, particularly at the instant of their evolution, have a constant tendency to outstrip it, and therefore impel it with an intensity which depends on the relative velocity of the two bodies. The transmission of this excess of velocity from one to the other is by infinitely small degrees, and their action ceases when the velocities become equal. This velocity, accumulated in the projectile, is not the product of the instantaneous effort and pressure of the gases, but rather the sum of the efforts which they have exerted against it.

143. The motive force of the gases will evidently be a maximum when the complete combustion of the charge takes place in the place which it occupies. It will be necessary to carefully distinguish this force, the motive force, from the useful effect.

The motive force is the variable effort which the gases exert upon the projectile, and its intensity is equal to the accelerating force multiplied by the mass of the projectile.

The useful effect, on the contrary, is nothing but the resistance overcome in the direction of motion. The useful effect, at any point of the bore, is equal to half the living force, or to $\frac{MV^2}{2}$, V being the velocity of the projectile at this point.

144. If we admit that the displacement of the resistance is not the result of a sudden impulse of the gases, but rather the mechanical effort which they exert against it, we perceive that the force of the pow-

Preliminary ideas.

der, even at the instant of its evolution, has nothing absolute, but will depend on the resistance to be overcome. Experiment shows that the initial motive force of the gases depends on the weight of the projectile.

145. The gases evolved by the combustion of the charge acting constantly upon the projectile during its passage along the bore, impress upon it an accelerated motion. The velocity which it will have acquired on leaving the gun, or its initial velocity, will then evidently depend :

1st. On the intensity of the accelerating force at each instant of the time it acts on the projectile (that is, the law by which the accelerating force varies); and 2d, on the time during which the force continues to act.

A very quick powder almost instantaneously gives a violent impulse to the gun and projectile, displaces the latter, and drives it out of the gun ; but the motive force being suddenly developed, decreases very rapidly when the gases expand into a greater space, become less dense, and lose their caloric.

A slow powder produces a more tardy displacement of the projectile, and impresses upon it as well as the gun a less violent impulse ; but the projectile, moving less rapidly, is a longer time subjected to the action of the gases; and this effort itself decreases less rapidly, because the combustion of the charge is only completed during the passage of the projectile along the bore, which partly compensates for the loss of tension which the accelerating force has experienced by the decrease of density, and the diminution of the temperature of the gases already evolved.

If, then, the projectile does not too readily yield to the action of the gases, and the gun is of sufficient length to allow the time during which the action con-

tinues to compensate for the less intensity of the slow powder in the first instants, it may well happen that the projectile has, on leaving the gun, an equal or even a greater initial velocity than a quick powder would have communicated to it. On reflection, we must admit that the initial velocity is nothing but the sum of the partial accelerations of velocity which the projectile has received, and that a great number of slight accelerations, which slowly decrease, may equal or even exceed a smaller number of accelerations, much greater in the beginning, but rapidly decreasing. Preliminary ideas.

146. Slow powder should be superior to quicker powder, when the charge is heavy, the resistance to be overcome is considerable, and the gun is long. In mortars, a species of arm the bore of which is very short, the time during which the motive force acts upon the projectile is necessarily of short duration, at least when the resistance to be overcome is not very great. For these pieces, it is necessary that the motive force should be rapidly developed, or, in other words, that the powder should be quicker proportionally as the projectile is lighter.

In small arms, the ball yields to the slightest development of the motive force; if, therefore, the projectile is not driven rapidly along the bore, the period of contact of the gases with the sides of the bore is prolonged, a sensible loss of the temperature of the gases follows, and consequently a great diminution of their living force.

The powder which produces the maximum effect in small arms should, therefore, be quick.

In cannon, the combustion of the charge developes so great a heat, that the portion absorbed by the sides of the bore is scarcely sensible; in the second place, the effect of the motive force is continued for a longer

Preliminary ideas.

time, because the projectile is not so readily displaced as in small arms, and because its passage along the bore occupies a greater time than in mortars; consequently, it is possible for a motive force instantaneously developed, but acting upon the projectile but a short time and with a rapidly decreasing intensity, to produce a useful effect less than another force, the intensity of which is subject to less sudden variations, and which acts for a longer time upon the projectile.

Slow powder may, therefore, be superior to quick powder in guns, particularly if the charge is great, the projectile heavy, and the length of bore considerable.

At the same time we should remark, that if it is important that in cannon the development of the motive force should not be too rapid, too slow a combustion of the charge would be equally injurious. This relative velocity of combustion is better obtained by a free transmission of the consuming flame than by great combustibility of the grains themselves.

147. Experiment fully confirms the results of this reasoning: quick powders show a marked superiority in short pieces, such as mortars, and particularly in small arms; but this superiority diminishes as the length of bore, the calibre, the charge, and the resistance to be overcome increase, and we soon reach the limit at which, with slower powders, we obtain a greater useful effect.

148. It follows, from a comparison of experiments, that to produce the greatest useful effect, the powder should be proportionally quicker as the time during which the gases act upon the projectile diminishes, and as the charge decreases: in this last case a slight influence upon the combustibility, or an inconsiderable loss of caloric, become sensible.

It is also shown, by these experiments, that in small

arms and mortars, particularly those of small calibre, quick powder gives a much greater velocity to the projectile than is given by slow powder. In cannon, on the contrary, slow powders communicate to the projectile a greater velocity than quick powders, and this will be greater as the calibre of the gun increases, the bore is longer, the windage less, the projectile of greater weight, and the charge greater. Preliminary ideas.

149. The charge and the weight of the projectile being fixed, there exists for each arm a powder of a given combustibility which produces the maximum useful effect, supposing the purity of the ingredients and their proportions constant. This combustibility varies with the ratio of the charge and the weight of the projectile, and diminishes as the charge and the resistance to be overcome increase.

150. Cannon, in common with other machines, can usefully employ but a part of the motive force, and it is easily conceived that this useful part is comparatively small, on account of the considerable losses experienced by the escape of the gases by the vent, the windage, by the muzzle on the departure of the projectile, and finally by their friction against the sides of the bore.

The useful effect of the gases is represented by the half of the living force of the projectile, which is equal to the product of the square of the initial velocity by its mass.

The useful effect is equal to the difference of the effects of the motive force usefully employed and the effects of the injurious resistances; the last consist:

1st. In the recoil of the gun and carriage.

2d. In the friction and shocks of the gases against the sides of the bore.

3d. In the friction and shocks of the projectile against the same.

Preliminary ideas.

4th. In the effect lost by the gases which escape uselessly, and those which are dispersed in the air on the departure of the projectile.

151. The useful effect of the unit of weight of a given powder varies with the species of gun, and with the ratio of the charge; it depends principally:

1st. On the length of bore.

2d. On the ratio of the charge.

3d. On the amount of windage, and diameter of the vent.

4th. On the shape and capacity of the place which contains the charge.

5th. On the calibre of the gun.

6th. On the resistance to be overcome.

Of the influence of the length of bore.

152. The length of a gun exercises a great influence upon the effect of the charge, and this influence is greater in proportion as the gun is shorter. We must admit that the velocity of the projectile, and therefore the useful effect of the motive force, should increase with the length of bore up to a limit which is seldom reached in practice; for, that an increased length of bore should not cause an increase of velocity, it would be necessary that the force which accelerates the motion of the projectile should be less than the forces which retard this motion, which are the resistance of the air, and the friction and shocks of the projectile against the surface of the bore. It would, therefore, require an excessive length of bore to produce an equilibrium between the tension of the gases and these resistances.

This length varies with the charge[1]; thus, experi-

[1] Vide Piobert, Cours d'Artillerie—partie theorique, p. 104.

ments made in France have shown that the maximum effect is generally produced by a length of about 17 calibres with a charge of $\frac{1}{4}$, 18 to 19 calibres for a charge of $\frac{1}{3}$, and 19 to 21 calibres for a charge of $\frac{1}{2}$; the effect did not, however, greatly diminish until the length was diminished to 14 calibres, and it was also ascertained that in guns of small calibre the maximum effect was produced by a greater proportional length.

For cannon of ordinary length, and service charges of powder, the initial velocities increase as the fourth roots of the length of bore: therefore the *useful effect* increases as the square root of the length.

Of the ratio of the charge in the same gun.

153. The determination of the charge which produces the maximum effect, is intimately connected with the preceding considerations. Thus, there is a relative charge for all guns which produces the maximum velocity of the projectile, and this charge increases with the length of the gun: beyond this maximum the velocity decreases with the increase of the charge, until it becomes almost null when the gun is filled with powder, but the recoil of the gun always increases with the charge.

From this, we see that an excessive charge is as injurious to the effect required to be produced as an excessive length of the gun.

The initial velocity of a projectile is that with which it leaves the gun: this velocity, for charges which differ little and do not exceed half the maximum, is nearly proportional to the square root of the charge divided by the weight of the projectile. This analogy gives too great a result when we pass from a small charge to a greater, and one too small when we pass

Influence of the ratio of the charge.

from large to smaller charges; which shows that the effect is somewhat greater as the charge is smaller, a phenomenon which may, perhaps, be attributed to the retarding effect of the mass of the charge and its state of division.

The velocity may be determined with greater accuracy by the following formula of Piobert: Let b represent the weight of the ball, c that of the charge, v the initial velocity, and M a constant depending on the length of gun, windage, and kind of powder. $v = M \sqrt{\text{Log}\,(1+\frac{c}{b})}$.

The value of this co-efficient M has been determined by Major Mordecai, of the United States Ordnance Corps. For the service powder in current use, and the regulated windage, he has assigned to M a value of 5,200 for the 32-pounder gun, and 5,400 for the 24.

The maximum charge ought always to be greater for small than for large calibres; its weight should also differ little from that of the projectile. Mordecai, Second Report, p. 68, says, the charge of two-thirds of the weight of the ball may be considered the maximum charge, beyond which the velocity of the ball does not increase with the quantity of powder. According to Colonel Duchemin, the velocity produced by the maximum charge is to that produced by the half of that maximum as 15 to 14. The latter proportion should therefore never be surpassed.

In the same gun, discharging projectiles of the same weight, the useful effect being as the squares of the initial velocities, it follows that these effects are as the charges.

With a charge greater than half the maximum, the combustion of the powder is not entirely finished when the projectile leaves the gun; and in this case the useful effect increases in a ratio less than the charge.

Of the amount of windage.

154. To ascertain the maximum effect of the charge, we must consider the importance of windage.

The windage ring—that is, the difference between the diameter of the bore and the projectile—by its increase, sensibly influences the effect of the powder, because the gases which escape through it are wasted.

The tension of the gases in the rear of the ball will diminish as the windage and vent increase, for we know that the smallest aperture for their escape diminishes their tension in a great degree.

The quantity of gas which escapes by the vent and windage will be greater in proportion as the charge is smaller and the piece of less calibre.[1] The loss of force by the vent does not, in general, become sensible, except with very small charges; but the gases which escape by the windage ring often diminish the effect of the charge one-third, or even one-half. In every case the loss is relatively less as the powder is quicker and the charge greater. For the same gun, and same charge of the same kind of powder, the loss of velocity by windage is proportional to the windage. The absolute loss of velocity, by the same proportional windage, is nearly the same in different guns; the ratio of this loss to the total velocity is also nearly constant with the same proportional charges.

It would therefore appear, that to obtain the greatest effect from a given charge, we should reduce the windage to a smaller amount as the charge decreases; but as it is impossible to vary the diameter of the projectile, we have adopted certain mean dimensions which satisfy the necessities of the service.

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[1] According to Mordecai, (Second Report, p. 60.) and Expériences à Gavrés, the loss of velocity by a given windage, appears to be independent of the charge.

Of the shape and capacity of the place which contains the charge.

155. The shape of the place which contains the charge, or the chamber, if this is not a part of the bore, may diminish the effect of the charge. 1st. By an improper relation between its surface and capacity. 2d. By leaving a vacant space between the charge and projectile. 3d. By too great an orifice.

It is evident that the more closely the chamber resembles the body, which, for a given volume, offers the minimum surface, the better will it fulfil the required conditions, that the heat should be most concentrated, and its absorption by the surface the least possible; if, at the same time, the projectile is in contact with the charge the gases will be of the greatest density, highest temperature, and greatest possible tension; if a vacuum exists, the first impulse of the gases against the projectile will be extremely violent; but, since this last is not yet in motion, there is a very sensible loss of living force (useful effect) uselessly employed against the surface of the chamber, which is violently strained by the gases which rebound from the projectile. The vacant space which exists between the charge and projectile, therefore, diminishes the propellant force of the charge; for this reason conical chambers, with equal charges, generally give less ranges than cylindrical chambers; and this difference is greater as the vacant space increases. Experiment has shown that the range will be increased by filling this space with a block of wood or other substance.

156. Although the *propellant* effect of the charge is diminished, the *explosive* effect is increased; and when the projectile is not immediately in contact with the

charge, the gun is liable to burst. We will endeavor to explain this phenomenon. When the ball is in contact with the charge, it gradually acquires its velocity by the successive evolution of the gases: but if there is a vacant space between the powder and ball, the gases evolved carry with them a portion of the powder which is either burning or not yet inflamed, and strike the shot with a certain velocity; the projectile resisting this shock by its inertia, the gases recoil by virtue of their elasticity, and compress those which continue to be developed in the chamber. From this there results a concussion which, increasing the temperature and the pressure, induces a complete combustion of the charge and an increase of tension, which may burst the gun before the inertia of the ball is overcome.

Influence of the shape and capacity of the chamber.

157. The size of the orifice of the chamber exerts an influence upon the initial velocity, and this influence is generally greater in proportion as the orifice is smaller, at least to a certain limit. For this reason cylindrical chambers, which are narrow and deep, give greater ranges than those which are wide and shallow; but, on the contrary, its surface becomes a minimum when its diameter is considerable with respect to its length; that is, double the height of the cylinder, whence it follows that the maximum effect of a chamber of less calibre can only be determined by the dimensions of its orifice. The most advantageous proportion between the length and diameter of the chamber would appear to be 3 to 1.

It is probable that the advantageous influence of a small orifice to the chamber should be attributed to the more tardy displacement of the projectile; therefore the smaller the surface opposed to the action of the gases, the greater will be their tension to overcome the resistance of the projectile; the combustion will, there-

Influence of the shape and capacity of the chamber.

fore, be confined in a small space for a greater length of time, and the action of the gases upon the projectile will be prolonged. It is also probable that the space between the projectile and the sides of the chamber (which is generally vacant), becoming greater as the diameter of the chamber increases, contributes to heighten the advantageous influence of the smaller orifice.

158. Although it is found that the tension of the gases is less in guns with conical or gomer chambers than those with cylindrical chambers, by way of compensation, the segment of the projectile which receives the first impulse of the motive force is more extended in the first case than in the second. In certain cases, then, it may happen that the effects may become equal, and that even with equal charges the advantage rests with conical chambers.

159. As the length of the gun increases, the influence of the chamber diminishes, until it becomes insensible at a length of about twelve calibres and a charge of one-sixth the weight of the projectile. For small charges, which completely fill the chamber, it is always advantageous; but, on the contrary, for heavy charges, it lengthens the space occupied by the powder, and diminishes the velocity.

160. Spherical chambers give the longest ranges. With other forms, the length of range is in the following order: 1st, pear-shaped chambers; 2d, parabolic chambers; 3d, cylindrical chambers; 4th, conical chambers. The inferiority of conical chambers is less marked as the charge is greater, and if the space not occupied by the charge is filled. Spherical and pear-shaped chambers have been abandoned on account of the difficulty of construction, loading the gun, and cleansing the bore; besides which, they strained the

gun more, and rendered the recoil more violent. The cylindrical chamber, connected with the bore by a conical slope, has been adopted by the ordnance bureau.

Of the calibre of the gun.

161. It must be admitted that the useful effect of a given proportionate quantity of powder increases with the calibre of the gun; because the heat developed follows a more rapid progression than the charge, and the loss of heat absorbed by the surfaces with which it is in contact is less sensible when the charge is great. This supposition is confirmed by experiment. Thence we may conclude, that the useful effect of similar charges in similar guns increases more rapidly than the charges.

We must, however, observe, that if in the same gun the useful effects vary as the charges, and if in similar guns the increase of useful effect is not sensibly in a much greater ratio, the effort of the gases, on the contrary, increases in a much greater ratio when we increase the resistance to so great a degree as to place it in equilibrium with the motive force.[1]

162. These observations afford another proof that we usefully employ but a very small part of the motive force; which should, perhaps, be attributed to the disproportion which exists between the force and the resistance of the projectile, and the short time during which it acts: a new proof that for heavy charges it is advantageous to prolong the time of action by employing a slower powder than for small arms.

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[1] Vide the Experiments of Count Rumford.

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Of the resistance to be overcome.

163. No force can act unless it meets with a resistance which tends to overcome it: if the projectile offers but a slight resistance to the action of the motive force, this last will displace it during the first instants of its development, with a velocity proportionally greater as the resistance of the projectile is less. It follows, that too light a projectile has the same inconvenience as too short a bore, for it shortens the duration of the action of the gases.

The resistance which the projectile opposes to the motive force is due to its friction against the surface of the bore, and its inertia; to which it is necessary to add a portion of its weight when the gun is fired at an elevation.

The friction of the projectile against the surface of the bore, and the inertia which it opposes to the motive force, increase in the ratio of its weight, and the resistance which the gases have to overcome is therefore dependent upon this last.

164. The initial velocities obtained with the same gun and same charge, but with projectiles of different weights, are nearly inversely proportional to the square roots of the weights; whence it follows that the useful effects increase as the weights.

165. It is generally conceded, in practice, that the same charge of the same powder always produces the same velocity, whatever may be the angle of elevation; but it must be admitted, all other things being equal, that the initial velocity of the projectile, and therefore the useful effect of the charge, increases with the angle of projection. This is evidently due to the increase of resistance due to that fraction of the weight of the

projectile, proportional to the sine of the angle of projection, which presses upon the charge. This increased resistance occasions a more tardy displacement of the projectile, and the force developed is slightly increased.

166. Various philosophers have endeavored to determine the volume and absolute tension of the gases produced by the combustion of gunpowder. Robins valued the force developed at 1,000 times the pressure of the atmosphere; Euler, Lombard, and Bernoulli, at 10,000, and Count Rumford at 50,000. This great difference of results shows that the experiments upon which they are based were made under different circumstances, and the only conclusion we are able to draw is, that the force developed is in proportion to the obstacles which prevent its expansion, the limit of which is not yet determined.

Having thus pointed out the influence of the principal factors, which, in conjunction with the combustibility of the powder, determine the useful effect of a given quantity of powder, we will briefly review the different species of gunpowder in service.

SPECIES OF GUNPOWDER.

167. In most countries, at least two species of gunpowder are employed, one of which, composed of large grains, is intended for service in cannon—the other, of a finer grain, for small arms.

The employment of two kinds of powder is founded on the manner in which different arms employ the motive force, and is perfectly conformable to the principles already developed. We will examine its advantages.

Species of gunpowder.

168. In small arms, the useful effect of the charge constantly increases, at least to a very distant limit, with the combustibility of the powder, and above all, with the principal element of the combustibility in arms of small calibre—that is, the fineness of grain. The decisive influence exercised by this element in small arms, should be attributed to two causes.

1st. That for small charges, the combustibility of the grains is more important than the free transmission of the flame.[1]

2d. That the relative density of coarse powder, although greater than that of fine powder when the diameter of the piece is considerable, diminishes in a more rapid progression than the diameter, and we reach a limit where the fine powder is denser than the coarse.

The causes which we have stated, viz., the smallness of the charge and the resistance, the sensible quantity, for small charges, of caloric absorbed,—which is proportionally greater as the gases remain longer in contact with the surface,—explain why the increase of the useful effect should be in the direct ratio of the combustibility of the powder, as it is observed to be in small arms.

169. If in small arms the useful effect is increased as the powder becomes quicker and finer, we know that in cannon, on the contrary, it is slow powder,—that is, powder composed of large grains of a considerable absolute density,—which produces the maximum effect.

170. Slow powders produce the inconvenience of

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[1] It is asserted that the finer English sporting powders contain a small quantity of the fulminate of mercury, to render them quicker. If this is true, it would account for the frequent accidents to fowling-pieces. Vide Greiner on Gunnery.

fouling the barrels of small arms; their less lively combustion induces a greater absorption of caloric by the surface of the barrel, from which follows a diminution of the temperature of the gases, which is greater as the charge is less. Species of gunpowder.

This diminution of temperature modifies the chemical combination of the ingredients; it forms more carbonic oxide; a part of the nitre is not decomposed, and combines with the carbonic and sulphuric acids which are formed; hence, the residuum is no longer sulphuret of potassium, which is exceedingly deliquescent, but a mixture of it with the sulphate and carbonate of potash.

Quick powders are highly injurious to the gun; but for small arms this objection is of little force, the strength of the barrels being so great that they are capable of withstanding the effects of the quickest, and, therefore, most violent powders.

Cannon, on the contrary, which require a slow powder, are of bronze or cast-iron; the first of these, sensibly of less tenacity than wrought-iron, wants the necessary degree of hardness; the second possesses hardness in a high degree, but wants tenacity, and above all, elasticity. The violent shocks occasioned by a quick powder would be a certain cause of destruction for iron guns, the more dangerous, since no visible sign warns us of the approaching explosion.

Thus, the powder which produces the maximum useful effect in small arms is not too injurious, and the strongest cannon powder is that which least strains the gun.

To satisfy these various conditions, we have adopted three species of powder,—cannon, musket, and rifle,—differing only in the size of grain and the glazing. To these may be added sporting powder, in which the

Species of gunpowder.

hardness, glazing, and fineness, is pushed to a still greater degree.

171. In the year 1846, Professor Schönbein, a German chemist, discovered that cotton, prepared by immersion in a mixture of nitric and sulphuric acids, became highly explosive and propellant. The attention of military men was at once attracted by the announcement of a discovery which promised important advantages, but a comparison of its effects with those produced by agents already known, demonstrated its inferiority for military purposes.

THE PROOF OF GUNPOWDER.

172. The proof of gunpowder is intended to verify the qualities which influence its useful effect, its preservation, and that of the arm for which it is destined.

The useful effect of powder depends upon its degree of combustibility and its intrinsic force.[1] The quality of preservation in magazines, or during transportation, is determined by the form, the polish, and the hardness of the grain, by the quantity of sulphur employed, but particularly by the quality of the nitre, on which depends its absorption of moisture, the principal cause of the damage which it sustains.

The more or less destructive effect of the powder upon the gun depends essentially upon the rapidity of its combustion, and the proportions of the ingredients. Beyond a certain limit of combustibility, powder promptly destroys the gun, particularly when it is of heavy calibre, and becomes highly explosive; the proportions of the ingredients determine the nature of

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[1] By the intrinsic force of gunpowder is meant that which is due to the purity of the ingredients, and their proportions.

the residuum. We have already stated in page 55 that the proportions which give a product of carbonic acid and nitrogen gases, and sulphuret of potassium, correspond to the maximum of useful effect, because the reaction is the greatest possible. Proof of gunpowder.

In practice, the defects of fabrication seldom permit us to reach this theoretical limit: in addition to carbonic acid, carbonic oxide is developed; a part of the nitre is not decomposed, and combines with the sulphuric and carbonic acids formed by the reaction of the components, and the solid residuum of combustion becomes a mixture of the sulphuret of potassium with the sulphate and carbonate of potash. The residuum becomes more deliquescent with the excess of sulphur, and is more injurious in its effects by corroding the gun.

173. The two factors of the useful effect, the combustibility and intrinsic force, modify it in a variable manner according to the nature of the arm: in one species it is particularly determined by the combustibility; in others, the velocity of combustion beyond a certain limit exerts but a slight influence.

It therefore follows that no gun can class the powders in an order which shall be true for all others, but that each species of gun, on the contrary, arranges them in a different manner.

The rapidity of combustion is considerably modified by the physical qualities of the powder, such as the density, form, and hardness of the grain, &c.; the intrinsic force, on the contrary, depends exclusively on the purity of the ingredients and their proportions.

To verify these two qualities by the same instrument is a difficult problem. If, for example, we use a cannon, even of small calibre, as a six-pounder, we may obtain with sufficient accuracy the intrinsic force,

Proof of gunpowder.

but the degree of combustibility, after we reach a certain limit, escapes investigation. If, on the contrary, we make use of the mortar eprouvette, or a musket, the influence of the combustibility will predominate too much, and will not permit us to eliminate the factors of the intrinsic force.

174. In those countries where the government fabricates gunpowder for its own use, the proof should be particularly directed to the determination of the combustibility, as its intrinsic force must be nearly constant, because the circumstances which determine it are themselves constant. Where the fabrication is abandoned to private manufacturers, it becomes necessary for us to assure ourselves in a rigorous manner not only of its combustibility, but also of its intrinsic force, consequently of the purity of the ingredients and their proportions.

If the chemical analysis of gunpowder could be depended upon, it would inform us of the purity of the ingredients and their proportions; by some empirical signs, and the density of the grain, we could then deduce the degree of incorporation, and nothing would remain but to determine its combustibility by the verification of its physical qualities.

But analysis does not furnish us with results which are rigorously exact; it also requires a considerable knowledge of chemistry, and more practice than is generally met with. Finally, it cannot supply the place of the proof of its force: when the powder has been damaged, it is, however, necessary to have recourse to it.

175. From the preceding considerations, the proof of new powder demands:

1st. The verification of its physical qualities.

2d. Of its combustibility.

3d. Of its strength.

Proof of gunpowder.

To these it will be necessary to add the chemical analysis for damaged powders, or those in which the purity of the ingredients or their proportions appear to be defective, and, finally, the hygrometric test, which tests its capability of being long preserved without deterioration; the quantity of moisture absorbed in given circumstances, depends upon the hardness and glazing of the grain and the quantity of sulphur which it contains; this last, as well as the purity of the nitre, can only be determined by analysis. For the method of performing this analysis, see Ordnance Manual, page 158.

176. The physical qualities to be verified are, the state of division of the ingredients, their intimate incorporation, the color of the powder, the hardness, form, and size of the grain, the quantity of dust which it contains, the water which it has absorbed, and, finally, its density and specific gravity.

By crushing some grains of the powder we may discover by the touch those particles of sulphur which have not been sufficiently reduced. The uniform color of the powder, when crushed, indicates its thorough incorporation. The color of the pulverized powder as well as that of the grains, should be of a slaty blue, not too deep; a dull color is an indication of the presence of moisture; finally, white and brilliant points on the surface of the grains show that an efflorescence of the nitre has taken place.

It should be so hard as not to be easily crushed with the finger in the palm of the hand, and should leave no beads or traces of foulness, nor throw off sparks when flashed in quantities of ten grains on a copper plate or sheet of white paper. The uniformity and size of the grain is determined by inspection, or by

Proof of gunpowder.

sieves of the regulation size: it should, when new, leave no trace of dust when poured on the back of the hand.

For the methods of determining its density and specific gravity, see Ordnance Manual, page 152.

Its combustibility is determined by burning a train of uniform thickness laid in a groove.

The most important proof consists in the verification of the strength. This is compounded of the combustibility and intrinsic force, and experiment has long since shown that this can only be determined by firing a service charge from the species of arm for which it is destined. It was not until lately, and after a series of experiments by Major Mordecai, that this method of proof was adopted. These experiments established the fact that for cannon the recoil of the gun furnished satisfactory indications of the order of strength. For small arms a small ballistic pendulum is recommended, into which the ball is fired from a barrel set in a permanent frame. These machines have been erected at various points where powder is received. For their construction or mode of operation the reader is referred to Mordecai's Experiments on Gunpowder, a work which should be in the hands of every artillerist.

NOTE.—Since the preceding article was written, the author has met with Major Mordecai's Second Report. From these experiments he has ascertained that the six-pounder field-gun classes the various species of powder in the same order, and with nearly the same *degree* of relative force as the gun of larger calibre: it may therefore be used for the purpose of proving powder.

CHAPTER V.

OF PROJECTILES.

177. The projectiles of artillery are generally of a spherical figure, this being the only form which admits the great velocities which are impressed upon them; for, the surface of the sphere being a minimum with respect to its volume, the resistance which the atmosphere opposes to the motion of the projectile is the least possible; if the sphere takes up a motion of rotation, the symmetry of its figure renders the effect of that resistance less irregular; and, finally, the centres of gravity and of figure are less removed than in any other figure, consequently the causes of irregularity are less numerous. If, on the contrary, they have an elongated and angular figure, they take up a very irregular motion of rotation, experience an increased resistance on the part of the atmosphere, and have but little accuracy of flight. Their figure.

178. The determination of the most advantageous figure to be given to projectiles, is not so simple as it at first appears; for the solution of the question depends upon physical considerations, as well as the conditions which they must satisfy in service; and although the problem appears to be resolved in favor of the spherical form generally in use, we should know the reasons why it has been adopted. Reasons for adopting this figure.

Reasons for adopting this figure.

179. The resistance of the atmosphere during the flight of the projectile greatly diminishes its effect, and it is the influence of its figure on this resistance which we should first consider.

If the elasticity of the air were perfect, and if its particles were independent of each other, the moving surface would impress upon these molecules a velocity equal to that which itself possessed, and the resistance would be proportional to the square of the velocity; but this supposition is not true, for experiment demonstrates that the resistance of the atmosphere increases in a higher ratio than the square of the velocity.

The air being highly elastic, when a projectile moves in it the anterior strata, to a certain distance, are condensed, their pressure increased, and a certain velocity communicated to them; these strata at first escape laterally, then rush in to fill the void in the rear of the body with an accelerated velocity, encountering the posterior hemisphere of the projectile with a less velocity, and exerting upon it a pressure proportionally less than that upon the anterior hemisphere, as the velocity of the body is greater; if the velocity of the body is sufficiently great, it may happen that this displaced air will not return to its former position until after the passage of the body, and a vacuum will be left in its rear: in any case, the resistance to its motion is influenced by the form of the posterior part of the projectile.

Plate I. Fig. 4.

For, the molecules in returning towards the trajectory of the projectile with an accelerated velocity, and as it were drawn towards a centre, describe a species of trajectory, and flowing in from every side, these currents, in meeting, form eddies. These eddies do not follow the projectile with a velocity equal to that of the body itself, but leave a space which curves

the following trajectories in such a manner that the convexity will be towards the centre, and the new eddies formed curve in a direction opposite to the first. These phenomena are similar to those which occur when we move a body in the water, the waves and eddies being similar; we see, then, that a rounded and elongated figure for both the anterior and posterior portions of the projectile would diminish the resistance. Reasons for adopting this figure.

180. These phenomena, being produced by several causes, are extremely complicated, and it is only by direct experiment that we have been enabled to obtain the resistance to bodies of different forms moving in the atmosphere. This resistance has been found to be least for a body rounded at the extremities and maintaining constantly the same direction, with a length of five times its diameter, and the greatest diameter at two-fifths from the anterior part; but as the projectiles of artillery assume various positions during their flight, there results a greater resistance to any other figure than would be offered to a sphere. Plate I. Fig. 5.

181. The sphere alone enjoys the property of offering the same surface, and the same resistance is opposed by the air to its motion; it also contains the same volume in less surface, and thus offers a less resistance than any other figure in the different positions which it successively assumes. Projectiles, from the manner in which they are fired, always acquire a motion of rotation, and being opposed by the resistance of the atmosphere during this motion, every other than a spherical figure produces great deviations; for, these partial resistances not being distributed symmetrically with respect to the direction of motion, there would not be a single resultant in that line. These deviations will be similar for a sphere, if the centres of gravity and of Advantages of a spherical figure.

Advantages of a spherical figure.

figure do not coincide; they will even occur in a perfect sphere, if it takes up a motion of rotation; in this case experiment demonstrates its existence, and its cause is easily explained.

182. For, suppose the sphere, besides its progressive velocity, takes up a motion of rotation, which we will also suppose to be around a vertical axis from right to left; the right side having a motion in the same direction as the centre of gravity, the friction of this part of the body against the stratum of air with which it is in contact, will render its motion more difficult than if this rotation did not exist, and will, in consequence, increase the density and lateral pressure of the strata on this side; the contrary will take place on the opposite side, for the motion of rotation will facilitate their escape; for this double reason, the sum of the lateral pressures will be greater on the right than on the left side of the projectile, which will, in consequence, be pressed to the left and will deviate towards that side.

183. The pressure of the condensed air upon the anterior surface will also produce a friction, which acts from left to right, and which will cause the projectile to deviate towards the right. It follows that these different causes, the effects of which vary with the velocity, may produce an irregular deviation, first on one side, then on the other. Vide Chap. ix.

184. The spherical figure also presents advantages for the entrance of the projectile into the gun; it rolls, instead of sliding, and injures the bore less; it is true that it rests on a point, but this objection may be made to all rounded figures, and even a cylinder has but a line of contact. Spherical shot cannot jam in the bore, which sometimes happens with oblong shot; these last also produce great injuries in the bore. It has

also been observed, in firing oblong shot, that they turn during their flight, and do not, as was supposed, strike with the end which was outermost in the gun. To all these advantages of a spherical figure, is added facility of moulding and convenience of proving before reception.

Windage.

185. The diameter of a shot bears a certain relation to that of the bore of the gun; this excess of the diameter of the bore over that of the shot, is called the windage, and its amount depends, 1st. On the degree of perfection which we have attained in boring the gun, and fabricating the projectile; 2d. On the expansion of the projectile when heated; 3d. On the accumulation of rust in the bore of the gun, and upon the surface of the projectile; 4th. On the foulness of the bore in long-continued firing; 5th. On the thickness of the straps which secure the projectile to the sabot. Formerly the windage varied with, and was one-twentieth of the calibre; at present it is fixed at the same amount for all calibres, viz., between 0.1 and 0.2 of an inch. It is evident that the windage should be a fixed quantity, independent of the calibre; for, of the preceding causes for admitting windage, the second alone depends upon the calibre; hot shot, however, are not used afloat, therefore this consideration is unnecessary.[1]

Species of projectiles.

186. Projectiles are divided into solid and hollow. We will now consider the conditions which they ought to satisfy.

The resistance of the atmosphere to two projectiles moving with the same velocity, is respectively proportional to their surface or to the square of their diameter, while the overcoming forces of these projec-

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[1] The expansion of a shot is generally admitted to be 1-70 of the diameter; therefore shot of a greater calibre than the 42 will not enter the gun wheu heated.

Species of projectiles.

tiles are proportionate to their mass, or to their volume multiplied by their density, or, in other terms, to the cube of their diameter by their density; but the effect of the resistance of the atmosphere will diminish, as the projectile has the greater overcoming force. The retarding effect will therefore be proportional to the square of the diameter divided by the product of its cube into the density of the body, or to unity divided by the diameter into the density. In short, the effect of atmospheric resistance upon two projectiles moving with the same velocity, is in the inverse ratio of their diameters multiplied by their densities.[1]

187. For projectiles of the same density, the effect of this resistance will be the inverse ratio of their diameters; for projectiles of the same diameter, but of different substances, the resistance will be in the inverse ratio of their densities; finally, that two different projectiles shall experience the same resistance, it is necessary that the products of their diameters by their respective densities shall be equal.[2]

188. The specific gravities and densities of bodies being proportional, may be substituted for each other (Art. 19). The specific gravity of a leaden ball being 11.20, and that of a cast iron one 7.43, the resistance ex-

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[1] Thiroux, p. 225.

[2] The *mass* and *density* of bodies are estimated according to their various degrees of porosity. The *mass* represents the number of material particles in a body: the greater the mass, the less porous the substance will be. *Density*, on the contrary, expresses the relation of the masses where the volumes are equal; i. e., *of two bodies, that is the more dense, which, with equal bulk, contains the greater mass.*

We have then the relations, the volumes being equal, $D : d = M : m$.

the masses „ „ „ „ $= v : V$.

Or the masses and volumes being unequal, . . $D : d = Mv : mV$.

$M : m$.

„ „ $= \frac{}{V} \quad \frac{}{v}$.

perienced by the leaden ball will be but $\cdot\frac{7}{11}\frac{4}{12}\frac{3}{0}$, or .6633 (a little less than two-thirds) of that experience by an iron ball of the same diameter. Although leaden balls would have greater range and accuracy of flight than those of iron, yet it is observed that they lose their form upon the first impact, even upon water, and lose in a great degree the advantage of a ricochet, whilst they have not a sufficient consistence to penetrate bodies which offer much resistance. Species of projectiles.

189. This defect has suggested the employment of compound shot, or shells filled with lead, which might, in certain cases, be advantageously employed. As wrought-iron balls have greater specific gravity, and are homogeneous, they would be superior to those of cast metal; but their high price will, probably, prevent their adoption. A wrought-iron ball of 24 lbs. weight will have nearly the same range and accuracy as a cast-iron shot of 32. We have then the advantage of a diminution of the weight of the gun, of the charge, and of the number of men employed to serve the gun, in the proportion of the respective weights of the projectiles. But as it is not probable that they will be supplied, we should endeavor to give our cast metal shot the greatest possible density. Compound shot.

190. The advantages attending an increase of calibre have caused the introduction of guns as heavy as the 32 into the smaller vessels; but as their slight frames cannot support the long gun, it has become necessary to decrease its weight. To restrain the recoil of these guns within proper limits, it was necessary to maintain a certain relation between the weight of the gun and projectile. This was effected by casting the shot hollow. This method, whilst it retained some of the advantages attending an increase of calibre, diminished the density in so great a degree that it is believed the Hollow shot.

point of compensation is never reached in guns of less than eight inch calibre.

Shells. 191. The objections to hollow shot being chiefly founded on their want of penetrative force, do not apply to them when filled with powder, or, as they are then called, loaded shells, since the only desirable penetration in these last is through the outside planking. The advantage of shells consists in the destruction of the sides of the vessel and the masts and yards, in which they lodge, in wounding a great number of men, and causing great damage to the materiel generally. Finally, the shell, by the terror which its explosions create, produces a moral effect even greater than its absolute effect, terrible as this last may be.

The fire is, in general, communicated to the powder contained in the shell by the aid of the *fuze*, a conical wooden plug, with a cylindrical canal pierced in its axis; this canal is filled with a composition which burns with a rapidity known by experiment. Col. Huger, of the Ordnance Department, has effected an improvement in the fuze which has greatly increased the efficiency of shells and spherical case. The composition is driven in a paper case, and inserted, at the moment of loading, in a wooden plug, previously driven in the fuze hole, and accurately reamed out: for the Columbiads the plug is of bronze.

Attempts have been made to avoid the use of the fuze, by causing the shell to explode by percussion. The results of the numerous experiments which we have made to test these percussion shells, have not transpired; but it is to be inferred that they were not favorable, since they have not been adopted. Percussion shells are in general oblong; and there still remain in our arsenals such shells, some of which are furnished with vanes at one extremity, to give the shell a whirl-

ing motion, and cause it to strike with the end which is outermost in the gun. Experiments in other countries have demonstrated the inefficiency of such means, and also the inferiority of the percussion shell, and they are not at this time used in the English or French marine. Shells.

192. Those hollow shot or shells which are greatest, having at the same time a greater relative density, have the greatest accuracy of flight; but as it is necessary that these projectiles should contain a charge bearing a certain ratio to their thickness, that a required effect may be produced when they burst, we are obliged to restrain their thickness within certain limits determined by experiment; it is also necessary to consider the ratio which should exist between the weight of the projectile and that of the gun.[1]

193. The mean density of hollow shot will increase with the weight of the shot with respect to its volume, and the relative effect of atmospheric resistance upon the projectiles of the same diameter will be in the inverse ratio of their weight. Hollow shot are sometimes filled with sand or lead to increase their weight. This principle has been successfully applied in the manufacture of spherical case, which are filled with leaden balls for the double purpose of augmenting their weight and increasing the number of missiles when they burst.

In general, the denser projectiles preserve their velocity longest, and with them the employment of heavy charges will be most advantageous. For, if an improper relation exists between the initial velocity and the weight of the projectile, it may impair its accuracy of flight, because an excessive velocity is promptly reduced

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[1] The shells employed in the navy weigh about three-fourths the nominal weight of the shot.

by the resistance of the atmosphere, particularly when the projectile is not of great density, whilst the motion of rotation which produces deviations is always increased by the employment of too heavy a charge; its range and accuracy may, therefore, be less than that of a projectile of greater density, fired with a less initial velocity.

Grape. 194. In certain cases it is advantageous to increase the number of missiles; to effect this object, shot of a smaller calibre are placed in tin cases, thence called canister, or case-shot, or secured in a canvas bag to an iron plate, which receives the impulse of the charge. These last, from the form which they assume, are called grape-shot. A better arrangement of the grape has been introduced from the French service. The plates are of wrought iron, and the shot, placed in three layers, of three in each, are confined by the plates at the end, and two rings inserted between the layers; the stem is headed at one end, and fitted with a nut at the other extremity. This arrangement, more durable and cheaper in the end than the old method, has the advantage of increasing the spread of the grape. Grape shot are of little service except on board small craft, to repel boats.

Plate I. Fig. 8.

Fig. 9. 195. Other forms of shot, as double-headed or bar-shot, star-shot, chain-shot, etc., have been constructed at various times, and have been occasionally found useful in dismantling a ship in chase. A shot of this nature, fired by the President when chased by the Endymion, took fourteen cloths out of the foresail of the latter ship, almost stripping it from the yard. At present, no such missiles are fabricated.

Fabrication of projectiles. 196. The projectiles employed by artillery are generally cast of soft gray or mottled iron; these species of iron are sufficiently fusible, whilst they have greater

tenacity than any others, and are of the necessary degree of hardness. If they were cast from brittle iron, they would be liable to break from the shocks received in the bore of the gun, or upon impact upon hard bodies. The fabrication of projectiles requires the operations of moulding, casting, and cleaning the surface. Fabrication of projectiles.

Projectiles may be cast in moulds of cast-iron, or of sand. Formerly cast-iron moulds, composed of two hemispheres, which, when united, formed a sphere, were exclusively used;—at present, they are cast in sand moulds. This method is the most expensive, because it is necessary to make a mould for each projectile, but it has the advantage of producing projectiles of greater sphericity and smoothness of surface, and also of a uniform and somewhat greater density. Shot cast in iron moulds contain cavities, and are also cracked by being heated.

When the moulds are made of sand, the method of moulding is the same as that already described for the manufacture of cannon. When the projectile is to be hollow, a core of moulding composition is formed between two hemispherical cups or shells, upon a stem of wood, and this stem is so fixed in one of the half moulds, that when the flasks are united the core shall be at the centre; the stem supports the core, and forms the fuze-hole. Several channels are made in the mould for the escape of the moisture and heated air, and introduction of the metal; the channel for the introduction of the metal is near the bottom of the mould, that the latter may not be injured by the falling metal, which is brought from the furnace in ladles and poured into the mould in a small stream, without interruption. The iron contracts in cooling; consequently, as the outer surface cools soonest, a cavity is formed in the interior of the shot; for this reason all shot, if floated

Fabrication of projectiles.

in mercury, will be found to have one side preponderate; that this cavity may be formed at the centre of the projectile, the mould should be occasionally turned, after the *jet* has set or become solid.

At the end of two hours, the casting being sufficiently hardened, the moulds are opened and the jets and seams removed with a hammer; the core of shells is picked out through the fuze-hole. In order to polish the shot and remove the irregularities upon their surface, they are sometimes re-heated and hammered. The anvil and hammer should have spherical cups to fit upon the shot, and the latter should be frequently turned while being hammered. A small stream of water is conducted upon the shot during the hammering, to assist in polishing its surface, which it does by insinuating itself between the coating of oxide and the metal, where it expands into steam and throws off the scales.

Proof of shot and shells.

Shot are examined to ascertain the depth of cavities on their surface, which must not exceed 0.2 of an inch; are passed through ring-gauges of the maximum and minimum diameters, and also rolled through a cylinder-gauge equal in diameter to the large gauge-ring; and are allowed to fall from a height of twenty feet upon a block of iron, to test their tenacity. The weight always exceeds the nominal weight.

The thickness of shells is examined with the *callipers*, and the size of the fuze-hole gauged; the shell is then placed in a tub of water, and air forced into it with a bellows through the fuze-hole, to ascertain if there are any air-holes or cavities.

CHAPTER VI.

THEORY OF PROJECTILES.

Of the Trajectory.

197. The ancients, although possessed of offensive arms destined to be used at a distance, had no idea of the form of the *trajectory ;* that is, the curve described by a heavy body which has received from an external force an instantaneous impulse of determinate force and direction, and is also subjected to the action of gravity. Upon the solution of this question of mechanics is based the theory and practice of gunnery.

A slight sketch of the phases which this problem has assumed at various epochs, will be instructive.[1]

First epoch in the history of the problem. 1537.

198. Tartaglia, an Italian engineer, was the first who published a theory for the trajectory ; the laws of compound motion, and those of falling bodies, were not yet sufficiently well known to allow him to determine the true curve described by a projectile. He represented it as formed of three segments ; the first, a straight line, the prolongation of the axis of the gun, described by a rapid movement ; the second, an arc of a circle ; and the third, a straight line.

Plate 1. Fig. 10.

He was, however, too well informed to believe that this heterogeneous system was the true trajectory, and is even careful to inform us that it is a curve in

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[1] Vide Cotty—Dictionnaire d'Artillerie. Thiroux, p. 329.

all its parts, and that his theory was merely given to aid in resolving the problem of ranges, the only subject which he proposed to consider. As the range is zero when we fire vertically, and also exactly horizontally, he concluded that there was an elevation between the horizon and zenith, which gave a maximum range. This angle of greatest range he fixed at 45.°[1]

Second epoch. 1638.

199. No further progress was made in the solution of the problem until Galileo discovered the laws of falling bodies, when it was conceived that the curve described by projectiles ought to be a parabola with a vertical axis: it was supposed that the air was not sufficiently dense to oppose a sensible resistance to their motion. The properties of the parabola furnish a simple relation between the four following quantities: 1st. The initial velocity; 2d. The angle of projection; 3d. The *amplitude*, or horizontal range; 4th. The vertical height to which the projectile attained.

Fig. 11.

According to the hypothesis that the trajectory is a parabola with a vertical axis, the summit of the curve corresponding with the centre of amplitude, we have, —The two branches similar and equal,—The angle of incidence is equal to the angle of projection,—The angle giving the greatest range is at 45°,—Angles equidistant from 45° give equal ranges,—At the same elevation the initial velocities are as the square roots of the ranges,—The velocity is the same in the two branches of the curve at the same height, and the final velocity is equal to the initial velocity,—With equal initial velocities the ranges are as the sines of twice the angles of elevation,—With equal charges the times

[1] Experiment and theory have since shown that this angle of greatest range varies with the density, the volume, and the velocity of the projectile. Art. 219.

of flight are among themselves as the sines of the angles of elevation, — In equal times the projectile passes over equal horizontal spaces.

This theory maintained its ground a long time, by virtue of its extreme simplicity. The curve described by a large projectile moving in the air with a low velocity is sensibly a parabola.

200. Newton first demonstrated the fact that this theory was erroneous. The resistance of the air being admitted, he assumed that it was proportional to the square of the velocity, and also proportional to the square of the diameter of the projectile. This hypothesis being generally admitted, the philosophers proceeded to resolve the problem of the trajectory, which they found to be a curve of two unequal branches, of which the first, on the side of the gun, approached nearer a straight line as the initial velocity increased, the curve becoming greater as it approached the summit. The second branch, formed during the descent, approached a straight line, and, if the height was sufficiently great, the fall was almost vertical. 1710.

201. Notwithstanding the simplicity of the hypothesis of Newton, the calculation of the trajectory could only be approximate, and with great labor, on account of the exponential expressions contained in the equations; but these approximations were sufficiently accurate in practice, as they coincided with the mean results of experiment; nevertheless, this coincidence can only be attributed to a compensation of errors, the expression for the law of atmospheric resistance not being well known. Experiments since made in England, France, and the United States, with the ballistic pendulum, have shown that the law of atmospheric resistance is much more complicated than was supposed by Newton. Third epoch 1719.

Third epoch. 1719.

202. Newton himself did not at first succeed in resolving the problem, and it was reserved for Bernouilli to determine it, an English mathematician, named Keill, having challenged those of the Continent to determine the circumstances of the motion of a projectile in the air, supposing: 1st. That the projectile was perfectly spherical and homogeneous; 2d. That the air was of uniform density; 3d. That the absolute resistance of the air is expressed by the square of the velocity, divided by the product of the diameter of the projectile by the ratio of its density to that of air, multiplied by a numerical co-efficient. This co-efficient was valued by Newton at $\frac{3}{8}$. Euler subsequently made it greater, and Lombard diminished it to $\frac{2}{40}$. This problem was first solved by Bernouilli, and subsequently by other mathematicians.

The true law of the retarding force as a function of the velocity is much more complicated: with very high or very low velocities it differs greatly from proportionality to the square of the velocity: it increases in a greater ratio for high velocities, and is sensibly proportional to the simple velocity for very low velocities.

For it must be admitted, that if the projectile has an initial velocity greater than that with which the air rushes into the vacuum, a void will be left in the rear of the ball; the latter by condensing the air in front, adds its elasticity to the atmospheric pressure, and considerably increases the resistance to the motion of the projectile, a circumstance not considered in the theory of Newton.

Fourth epoch. 1753.

203. After the appearance of the "New Principles of Gunnery," by Robins, Euler resumed the consideration of the problem.

Although it would appear that there is an infinite

number of curves, corresponding to the various conditions and circumstances of practice, yet he found that they were restrained within such limits that they could be divided into a certain number of classes. Those contained within each five degrees, from 0° to 90°, therefore gave eighteen classes; the curves corresponding to intermediate elevations were to be deduced from the others by interpolation. He therefore proposed to calculate eighteen tables, each of which should contain for its own species all the circumstances of its motion. This method, which is sufficiently accurate for considering angles of projection, involves a tedious calculation, and has the further disadvantage of requiring separate calculations for the two branches.

Fourth epoch. 1753.

The tables indicated by Euler, or others similar to them, have been calculated by various persons, and some have even had the patience to compute them for every degree to 75°.

204. At present the problem is generally considered as comprising two cases; the first, the fire under all angles of projection comprised between 0° and 15° above or below the horizon; the second, the consideration of the fire under great angles. Although the exact determination of this problem has not been attained, yet several authors have furnished solutions, which are sufficiently accurate in practice.

Fifth epoch Present state of the problem.

205. The first question which is offered for our consideration, is the determination of the velocity which results from the employment of a given charge for a known gun.[1] We have shown that this question can only be resolved in an approximate manner by more or less complicated formulæ, or with greater accuracy, by the aid of experiment.

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[1] Vide p. 94.

Initial velocities.

206. The subject of the initial velocities of projectiles, more interesting to practical gunnery than that of the trajectory itself, but also more difficult, has long engaged the attention of philosophers. A summary of the methods adopted to resolve the question will be interesting. These methods were of two species, à priori and à posteriori. By the first, they endeavored to deduce the force of gunpowder, and the velocity impressed upon a given projectile, by a known charge in a given gun. By the second, they measured in a more or less direct manner the velocity impressed upon the projectile by the charge, without entering into the consideration of the causes producing it.

1st. Determination of the initial velocity by the force of gunpowder.

207. The force of inflamed gunpowder is due to the elasticity of a fluid disengaged from the solid components at the moment of combustion. The general nature of this fluid has been explained in the article on gunpowder. This fluid, whatever may be its constitution, exists in gunpowder in a state of condensation, which is in the ratio of the initial energy which it exerts on all sides at the moment when it is liberated by the application of fire. Robins valued the force of condensation at 240 times the atmospheric pressure; but all philosophers agree that the initial force developed is greatly increased by the heat caused by the explosion. This force has been valued at from 1,000 to 50,000 atmospheres. (See page 101.) The determination of the force involves so many difficulties that we are unable to deduce from it the velocities.

2d. Lombard's method, or Horizontal ranges.

208. This method, proposed by Bernouilli, was adopted by Lombard with the necessary precaution of assuring himself of the angle of departure.

Lombard, considering that the inequality of ranges proceeds principally from the variation of the angle of departure, endeavored to assign a rule for this devia-

tion, so as to be able to determine the initial velocities from the ranges. His method consisted in procuring two points of the trajectory; by means of which, supposing the law of the air's resistance known, all the circumstances of the motion may be determined. Lombard's method, or Horizontal ranges.

The first point of the trajectory was determined by means of a very thin pine board, twelve inches broad, which was planted in the head of a stake, driven in the ground several yards in front of the muzzle of the gun. This distance was usually 48 feet, so that the blast of the gun might not reach and derange the board. The axis of the bore was carefully levelled, and its intersection with the stake marked upon it; after firing the gun, the distance from the centre of the hole in the board to this mark gave the angle of departure. The second point of the trajectory was the point of fall, the distance of which was determined by means of stakes driven in the ground at equal and known distances in the trace of the plane of fire.

According to Lombard, the angle of departure is seldom, if ever, equal to the angle of elevation of the gun; this difference was even $34'$; the mean was, however, $10'$ either above or below the direction of the axis of the gun.

The equation of the trajectory adopted by Lombard makes the ranges a little too short; but as he assumes the resistance of the air a little less than it really is, there is a compensation of errors, and his results may be relied upon in practice.

This method was adopted at Gavres for determining the velocities of the projectiles of the several classes of guns in the French navy.

209. The ballistic pendulum, invented by Robins, has undergone successive improvements, and at present it may be said to satisfy all the conditions required 3d. By the Ballistic pendulum.

in the determination of initial velocities. For a complete description of the machine and its mode of operation, see Mordecai on Gunpowder.

4th. By the recoil of the gun.

210. Another method of determining initial velocities, also due to Robins, and from which the idea of the recoiling eprouvette has been taken, is by the recoil of the gun when suspended by means of inflexible rods from an axis. This method is more simple than the ballistic pendulum, and the service of the pendulum is entirely dispensed with. Hutton did not experience that coincidence of results which was necessary to produce a reliance on its indications; but later experiments have shown that the recoil of the gun furnishes a satisfactory result.

5th. By the penetration of the projectile in different mediums.

211. By this method we first prepare a target of sufficient extent, homogeneous and penetrable. This may be a bank of earth, disposed in successive strata of uniform thickness, carefully rammed. The balls are then fired into it, observing the necessary precaution of firing into parts so distant that the disturbance produced by one of the balls may not facilitate the entrance of the others. We measure the penetration accurately and obtain the ratios of all the velocities to each other, by the principle that the velocities are in the direct ratio of the square roots of the penetrations, and in the compound ratio of the diameter of the ball and its specific gravity. Finally, knowing the initial velocity of one of the projectiles by the means already indicated, we at once deduce that of the others.

This method is the more valuable, as it is the only practicable method of determining the final velocity of the projectile, or that which it has at the point of fall.

6th. By the rotatory machine.

212. The rotatory machine consists of an axis, bearing at each end a disk of thin pasteboard, the

plane of which is perpendicular to the axis, and its centre coincident with that of the axis. The disks are about six feet in diameter, and are fixed on the axis in such a manner that they preserve their relative position when it is caused to revolve rapidly. They are divided into angles of one degree by radii, which correspond with one another on each disk. 6th. By the rotatory machine.

Supposing the machine set in motion, and its uniform velocity ascertained; if we discharge a gun, aimed in the vertical plane comprised between the two radii which correspond to the perforations made by the ball in each disk, it will be easy to find the velocity of the ball.

213. In England a velocity of eight revolutions, or 2880° in 1″ has been communicated to this machine. A cannon ball moving with the velocity of 1200 feet would pass through the interval between the disks 24 feet in $\frac{1}{50}''$; therefore $\frac{2880}{50}°$, or 50° .6, would be the arc described by the disks, which is sufficiently great to determine the velocity of the ball with great precision. Used in England to determine the velocity of cannon balls.

214. The second question to be considered is the determination of the form of the curve described in the air by a known projectile, moving with a given velocity, and fired at a given angle. This problem is only to be resolved approximately by the aid of some given theorems and clever speculations. In general these approximate methods are reduced to the consideration of the ordinates of the trajectory, as being the sum of 2, 3, or 4 lines, according to the circumstances of the case; as, a straight line—a conic parabola (of the second degree)—a cubic parabola (of the third degree)—an exponential line.

215. The trajectory in the air is a plane curve, continuous and infinitely extended; it cannot be cut by a straight line in more than two points, and is contained Form of the trajectory.

Form of the trajectory.

between two assymptotes, one of which is vertical and the other inclined.

The equation of this curve being transcendental, and involving a tedious calculation, different authors have substituted for it other and more simple equations, which are, however, only approximate, and have thus arrived at equations of various forms; they have, therefore, attributed to the co-efficients of these formulæ different values. The great uncertainty relative to the value of the co-efficient representing atmospheric resistance, occasions the frequent difference between the results of calculation and those of experiment. We can, however, advantageously employ these formulæ by combining them with the results of experiment.

216. We have shown, that without the resistance of the atmosphere, the trajectory would be a parabola with a vertical axis; but the resistance of this fluid being proportional to the square of the velocity of the moving body, and in the inverse ratio of its diameter multiplied by its density, it necessarily alters the symmetry of the curve, and straightens the descending branch of the trajectory quicker as the projectile is smaller and of a lighter substance. Therefore, bodies which are larger and more dense, will, when projected in the air under the same circumstances, range further; whilst, if they encountered no resistance on the part of the air, all projectiles thrown with the same initial velocity and at the same angle of elevation, would have the same range. This resistance diminishes the velocity of the projectile from the point of departure to a point situated below and near the summit of the descending branch of the trajectory; it then increases up to a limit which depends upon the diameter and density of the projectile.

Maximum velocity of fall.

Deviating force.

217. We have heretofore supposed the projectile to be solicited by but two forces, one of which is gravity, the other the resistance of the air, which is supposed to be nearly proportional to the square of the velocity and tangent to the trajectory. But a third force, which we may call the deviating force, acts upon the body: it depends, in general, on the density of the atmosphere, the velocity and motion of rotation of the projectile, on its diameter and density, its sphericity, and the position of its centre of gravity. The intensity and direction of the deviating force varies during the continuance of the motion. The action of this force is explained in Chap. IX.

218. It has long been known that the heaviest charges give the greatest ranges; the initial velocities also increase with the length of the gun; but the increase of atmospheric resistance due to the more rapid motion of the projectile,—a resistance which is increased by the violence of the motion of rotation impressed upon the ball by heavy charges,—destroys the greater part of the velocity; consequently, when the required range is great, there is little or even no advantage gained by employing heavy charges.

Angle of greatest range.

219. With a given velocity, the ranges increase with the angle of elevation, up to a certain limit, having passed which, they diminish. At 45° the range is at its maximum. This angle of 45° would be true for all calibres and all velocities, if the atmosphere did not oppose their motion; but in reality, it is only true with low velocities and heavy projectiles. In general, the angle which gives the greatest range should increase as the velocity diminishes, and as the projectile is less dense and of a smaller calibre. For the musket, the greatest range is given at 28° to 30°; for mortars, at about 42°.

Angle of greatest range.

In space, the angles of projection equi-distant from 45° (45°$\pm a$), give equal ranges. In the air, there are also two angles which give the same range, but these angles are not equally removed from the maximum.

220. When we fire under low angles, and nearly parallel to the surface, the mass of air driven before the projectile being unable to escape as freely below as above, reacts upon the projectile, and prevents its falling as much as if it were fired at such an elevation that the compressed air could escape freely in every direction. This occasioned the remark of an old artillerist, "The valley attracts the ball."

A ball fired over the surface of the sea falls a little more than if it were fired over the earth, as the water recedes a little from the shock given it by the compressed air; but it falls less than if it were fired at a great elevation and into an undefined mass of air.

According to Piobert, to whom this explanation is due, this effect, although small and not usually considered in practice, may, by its continuance, exercise a considerable influence, and make itself felt at an angle of 3°; the fall produced by a deep valley may be about two yards, and the elevation produced by a surface, three yards.

Ricochet firing.

221. When the angle of incidence is sufficiently small, the projectile rises and continues to bound forward, forming a series of ricochets, which increase in number as the angle of incidence is smaller and the medium more resistant and elastic. The projectile, in ricocheting, forms cavities which are of greater or less depth, but in all cases, in each ricochet the angles of reflection are greater than the angles of incidence, and depend on the elasticity and hardness of the surface struck, and also on the diameter, density, and velocity of the projectile.

If the surface is incompressible, as water, ricochet firing will be still more effective, and with a less loss of velocity, if the angle of incidence is not too open. When the angle of incidence is too great, the projectile buries itself, directing its course towards the side of least resistance.

The angle of projection remaining the same, if the charge be increased the angle of fall will increase; therefore the velocity of fall increases so long as the range does not exceed 1000 or 1200 yards, and then diminishes indefinitely; so that under the same angle, and within the limit of ordinary ranges, an increase of the charge may diminish the tendency to ricochet.

War rockets. Plate I. Fig. 12.

222. The trajectories of war-rockets, fired under small angles, have a form entirely different from those of other projectiles. This is owing to their velocity, after having rapidly increased, remaining nearly constant up to their point of fall, on account of the resistance of the atmosphere. The low initial velocity of the rocket makes the angle of greatest range from 50° to 60°, and the descending branch of the trajectory is straighter than the ascendant: consequently, when fired at low elevations, the angle of projection is greater than the angle of incidence.

CHAPTER VII.

OF POINTING AND FIRING CANNON.

Definition.

223. To point a gun, is to direct its axis towards the target, and give it the elevation necessary to enable the projectile to reach it. In general, the aim is taken with a line of sight (Art. 29) traced upon the surface of the gun, or passing through the most elevated points of the *sights;* but this method is not exact, except when this line is situated in the vertical plane which passes through the axis of the gun, which can occur only when the axis of the trunnions is horizontal (vide Chap. IX.) : if this should be the case, the position of the plane of fire is independent of the elevation given to the axis of the gun, and the first operation in pointing will be to cause the plane of fire to pass through the point to be struck. This is termed *giving the direction.*

Since, by the effect of the action of gravity, shot and shells move in a curved line from the moment they leave the muzzle of the gun from which they have been fired, it is also necessary that the gun should have a certain elevation given to its axis, depending upon the initial velocity, volume, and density of the projectile, and the distance of the target ; consequently, the problem to be resolved in the service of guns, is, so to determine the initial direction of the line of fire, that

the projectile, in its flight, shall strike an object whose distance is supposed to be known.

Formerly, the axis of the gun and the line of sight were made parallel, because it was supposed that the trajectory was the prolongation of the axis itself; at a later period, when it was known that this supposition was inadmissible, it was thought that the first portion of the curve described by the projectile was a straight line, followed by an arc of a circle, or a parabola. These errors arose from the fact that the trajectory has but a slight curvature in the ascending branch.

The first fabricators of cannon who observed this fact, presumed upon the ignorance of the true principles of gunnery displayed by the rest of the world, and announced that they possessed a secret means, by the aid of which they could considerably increase the range of guns. This means consisted simply in increasing the diameter of the breech; consequently, that the line of sight should be horizontal, it became necessary to elevate the muzzle, thereby increasing the point-blanc.[1] This secret was soon known to all the world, and led to the establishment of such an angle of sight as placed the *point-blanc* at the distance which usually separated the opposing batteries.

224. The projectile, on first leaving the gun, follows the direction of the axis A B, intersects the line of sight at E, rises above it, but falling again, intersects it at D: the distance of the point D from the muzzle of the gun, is called the *natural point-blanc.* The

Point-blanc. Plate I. Fig. 24.

[1] It is supposed that the similar ignorance of the naval world, caused the general adoption of carronades, at present considered so inefficient; the dispart of these guns being much greater than that of long guns, within the limits of practice, the line of metal elevations to reach a given range were nearly equal: consequently, the powers of the carronade were greatly overrated.

greater the natural angle of sight, the greater will be the length of the trajectory, and the more distant the point-blanc.

The aim at point-blanc presents no difficulty: but when the object is more distant, we must aim above it; and since the object can no longer be seen,—for the muzzle of the gun intercepts the view,—the aim becomes more incorrect as the elevation is increased.

Aim at an elevation.

225. Within the limits of practice, the ranges of all guns increase with the angle of elevation of the axis of the gun; we should, therefore, exactly determine the angle formed by the axis and the line of sight passing through the object to be struck. This is, in general, accomplished by means of a *tangent sight*, a species of graduated scale moving in a vertical plane at the breech, which, by increasing the diameter of the breech, increases the angle of sight, and consequently the range, while it permits us to see the object directly. The line of sight, and the point-blanc obtained by means of sights, are called *artificial*, to distinguish them from the line of metal sights and *natural* point-blanc.

Plate VII. Fig's 2, 6, 7.

For distances less than point-blanc, it is necessary to diminish the angle of sight, by placing a sight upon the muzzle or at the reinforce. This, however, would be inconvenient at sea; consequently, we have adopted either a *dispart sight*, or a fixed *front sight* (figs. 3, 4,) at the reinforce,[1] with a movable tangent scale at the breech. With the first, we have a permanent line of sight, parallel to the axis, and consequently no natural point-blanc. If the second is used, the line of sight is parallel to the axis when the tangent is at zero; but by

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[1] If this were placed upon the muzzle, it would be liable to be knocked off in loading, or by the recoil of the gun.

raising it, we obtain direct view of the object, and artificial lines of sight at all distances within the range of the gun.

English definition of point-blanc.

226. We have adopted from the English, another definition of point-blanc—that is, the distance of that point at which a shot fired from a gun, the axis of which is laid horizontally, and loaded with its full service charge, crosses the horizontal plane on which the trucks of the carriage stand: consequently, by this definition, the point-blanc range varies, not only with the calibre and charge, but also with the height of the carriage. The mean point-blanc, by this definition, varies from 275 yards for the 18, to 400 yards for the 32. The point-blanc of all the guns in use at sea, is, or should be, in harmony,—that is, their line of metal ranges should be equal. It has been fixed at about 800 yards, the penetration at this distance being sufficient, while the distance is sufficiently great to exhibit all the advantages of superior gunnery.

Difficulty of pointing at sea.

227. It is necessary that we should pay the utmost attention to the subject of pointing, for whatever perfection we may have attained in the fabrication of cannon or their projectiles, it will be impossible to attain the maximum of effect due to the pains we have taken, unless we employ, in the pointing, those means which are indispensable to give the fire the greatest precision. If it is found difficult on shore to strike a fixed object with a projectile of the most regular form, fired from another point equally fixed, and at a distance from the first which has been well ascertained, how much more difficult must it be to obtain the same result at sea, where the points of arrival and departure of the projectile are constantly changing their positions; where the motions of these points are neither regular nor definite; where the distance which sepa-

rates them can only be ascertained in an imperfect manner; where the powder, by its exposure at sea, has lost a portion of the strength it had at the time of proof, despite all the care we have bestowed for its better preservation; where, finally, the resistance which in ordinary cases the atmosphere opposes to the motion of the projectile, is modified by the strength of the wind.

These combined causes of error make the practice of naval gunnery an art much more difficult to acquire than that of artillery on shore; we should, consequently, endeavor to reduce to a minimum all these causes of error. To accomplish this reduction, Colonel Jure, of the French army, invented a system of sights intended to regulate pointing guns at sea.

Plate VII. Fig's 6, 4.

Description of tangent sights.

228. This system consists of two principal parts —of a *front sight*, fixed near the extremity of the reinforce, and of a *sight*, properly so called, consisting of a slide of wrought-iron, having a notch at its upper extremity, and sliding in a brass case fixed to the breech of the gun, perpendicular to the axis; this slide, or tangent scale, is divided by horizontal lines or notches, which correspond, for each charge of powder, to the distance which separates the gun from the target. It is usual to have but six principal divisions, subdivided by four, each division representing a cable's length, as being the unit of measure most familiar to seamen, and numbered downward from one to six, this last being the greatest distance at which a sea-fight should take place, that there may be no expenditure of ammunition without producing a useful effect.

Mode of using it.

229. The commanding officer, or officer of division, ascertains the distance with all the accuracy in his power, and orders the necessary elevation of the scale. When the officer has made known the distance,

the duty of the captain of the gun is very simple; he raises the scale to the notch which indicates the corresponding distance, and points horizontally at the object he wishes to strike, as if the projectile followed in a straight line the visual ray, whilst it really describes a line curved in all its parts.

Causes of inaccuracy.

The mobility of the points of departure and arrival of the projectile, of which we have spoken, and the continual variation of the angle of elevation during the rolls, are among the causes which act incessantly to prevent an exactitude of fire at sea. All of these causes of inaccuracy may be diminished; there are, however, others which cannot so readily be controlled.

Firing guns.

230. The application of the percussion principle to cannon, was one of the most important ameliorations in naval gunnery; for the instantaneous communication of fire to the charge, while the aim is on, is an essential to accuracy of fire at sea. Formerly, guns were fired by means of a match or port-fire applied to a train of powder poured into the vent; the slowness of this method, and its want of certainty,—for unless the cartridge was of a sufficient diameter to fill the chamber, the train was seldom connected,—rendered it necessary to adopt some other mode of firing guns. Subsequently, the invention of *tubes* greatly increased the certainty of fire, and the rapidity of its communication; this method is complicated, because it requires the use of three articles, the tube, the priming, and the match. If either of these is not well prepared, or is damaged by keeping, the fire is very uncertain; thus, if the tube misses fire, it is necessary to wait some time to see whether it hangs fire, before it can be replaced without danger; rain or sleet, by damping the priming, prevents it from taking fire; at night, it is difficult to prime or apply the match properly, and

Firing guns. the match is necessarily applied by another person at the order of the captain of the gun.

231. The discovery that preparations of mercury and other metals, and also a mixture of chlorate of potash with a combustible substance, exploded by friction, or a shock, naturally led to its application to fire-arms. This application was easily made, for the percussion lock is a much simpler piece of mechanism than the old flint lock. Great difficulty was, however, experienced in applying this method to cannon; it required the use of a lock secured upon their exterior, liable to injury from accidental shocks, and the blow of the hammer or other means used to explode the fulminate, injured the vent of bronze cannon; the forcible rush of the gases from the vent, also made it necessary to withdraw the means which had caused the detonation from their action.

232. For field artillery, the employment of the percussion principle, which is peculiarly liable to the first objection, has led to the invention of various methods of exploding the primer by friction; none of these methods have been adopted in our service, where, for field artillery, the tube, port-fire, and match are still employed. For heavy garrison and ship guns, we have, after numerous trials, obtained a form of percussion-lock (Hidden's patent sliding-lock), and a primer adapted to it, which appear to satisfy all the required conditions. It is simple, solid, stable, does not interfere with the pointing, and, after exploding the primer, the hammer is drawn back clear of the rush of gases from the vent.

Plate VII. Fig. 1.

The fulminating compound employed in the United States naval service, is not known to the author; the primers prepared with it, are not satisfactory. A mixture of chlorate of potash, sulphuret of antimony, and

mealed powder, in equal proportions, forms a more certain powder than the preparation of mercury; for small arms, and bronze cannon, it is objectionable, because it corrodes the metal, and it is also more liable to injury from moisture; it is, however, less dangerous to manufacture, and it does not readily explode by friction. Firing guns.

233. The primer at present used, is a pasteboard cup, half an inch in depth and diameter, with a small quantity of fulminate at the bottom; the cup is covered with a water-proof varnish; this cup is placed upon the head of the hammer, and pressed down forcibly with the thumb. By an inspection of the lock (Fig. 1, Pl. VII.), it will be seen that, until after it has struck upon the vent and exploded the primer, the pull upon the laniard causes the hammer to turn upon the bolt *a*; the hammer is then drawn back to the position shown by the dotted lines, clear of the rush of gas from the vent.

The percussion primer, when well made, has the advantages of permitting a greater rapidity, certainty, and accuracy of fire; it is more economical and less dangerous in service, and permits the captain of the gun to fire it himself, thus dispensing with the services of one man.

CHAPTER VIII.

UPON THE TANGENT SIGHTS IN USE, THEIR EMPLOYMENT, AND UTILITY.

Motion of projectiles.

234. Projectiles obey the laws common to all bodies left to themselves, from the moment they leave the muzzle of the gun; and, with the supposition that they receive no shock which may cause them to deviate from the line passing through the axis of the gun, they move for an infinitely short time in the direction of that line, and depart from it to a greater extent in a given time, as their velocity diminishes.

But whatever may be the fall of a projectile below the prolongation of the axis of the gun at a given distance, it is evident that to reach an object which may be at that distance, it will be necessary to give the axis of the gun such a direction that its height above the object shall be equal to the depression; and, as we should be able to fire at all distances between the gun and the point of first graze at the greatest elevations, it is necessary to know all the points of the curve described by the projectile.

These points are determined either by calculation or experiment, or, in a still better manner, by combining the results of both. Since this curve changes its form in but a slight degree between the limits of 0° and 15° above or below the horizon, if we, by a great

number of experiments, determine the position of three of its points, say at point blanc, 5°, and 10°, we can, by calculation, interpolate the position of the intermediate points with greater accuracy, than we can determine them separately by a limited series for each; for the value of the mean is in the direct ratio of the number of experiments from which it has been deduced. Motion of projectiles.

235. Formerly, guns were pointed either by the line of metal, or by a dispart sight, which gave a line of sight parallel to the axis; the aim then depended entirely upon the skill and knowledge of the pointer.

The aim by the line of metal had the disadvantage of requiring us to aim below the object, if it was nearer than the point-blanc range; and if the object was beyond that distance, the muzzle of the gun intercepted the view: with the dispart sight the object was never seen, and, in consequence, the hitting was a matter of chance, not the result of accurate pointing.

But the invention of tangent sights made a complete revolution in the system of pointing guns at sea, by leaving nothing to the judgment of the pointer, except the instant when three points are in the same line, a matter depending more upon natural aptitude than any degree of training.

These sights have given to pointing an accuracy, facility, and promptitude, never before attained. It is true that in close action, where the smoke hides the combatants from each other, the sights lose their advantages; but any system is in such circumstances almost useless; they are, however, invaluable when we are at a distance, for the fire is then slower, and the smoke, being dispersed by the wind, does not hinder the pointing.

236. As to the utility of tangent sights, with or

Utility of tangent sights.

without tables of ranges, there can be but one opinion among educated artillerists.[1] But let us compare the reasoning of the practical gunner and that of the instructed artillerist. If we say to the first, We see at such a distance an object which we wish to destroy, what ought to be the charge of powder and elevation of a given gun? The most intelligent will answer, Let us try; if the first shot strikes too low, or falls short of the object, I will give it greater elevation; if too high, depress the piece. He then fires a first shot, which he calls a trial shot; then a second, which is often but a second trial shot, followed by many others, losing most precious time, because the trace of each shot is lost in the water, and there are no means of ascertaining how much better the last is than the first; and should it attain the object, he has no means of ascertaining whether it has or has not penetrated. If we interrogate the second, he answers—It is necessary that the projectile, on attaining the object, should have sufficient force to produce the required effect. To produce this effect, when fired from a given gun, placed at a given distance, it must have a certain initial velocity: that it may leave the gun with this velocity, it is necessary that it should be fired with a certain charge of powder, of a known quality. Finally, knowing the dimensions of the given gun, and the initial velocity of the shot, it is necessary to know the elevation required; yet, knowing all these I am not certain that the required effect will be produced by each shot, because the anomalies known to exist may render the most carefully conducted practice at times uncertain.

237. The use of tangent sights and tables of ranges is therefore to be considered only as a means

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[1] Lombard.—Tables du tir.

of reducing the errors of estimation; for even when firing from a fixed battery, we observe great variations between two successive rounds fired from the same gun, with the same charge of the same powder, and at the same elevation. We must, consequently, expect as great differences between the results given in the tables and those obtained in presence of an enemy. For these reasons, tables of ranges form but the first term in the series of approximations, by the aid of which an instructed artillerist attains a degree of accuracy which the practical gunner can never equal; the former obtains the assistance of all the aids in his power, and without placing a blind confidence in the results he has collected, is understandingly guided by them in practice; the latter, with but vague and general ideas upon the subject, is only successful by accident. Utility of tangent sights.

238. The French were the first to apply sights to cannon, and from them most nations have borrowed the system. Colonel Jure, to whom they are indebted for the established arrangement, is content to determine the elevations to be given the scale for a limited number of distances, and under the ordinary conditions of a naval combat. Invention.

The best distances at which this should take place are from 600 to 1200 yards, or three to six cables' lengths. This distance being sufficiently great to develope all the advantages of superior gunnery, while we still retain penetrative power. It has appeared more simple to take the cable's length as the unit of measure, as being more familiar to seamen, which was originally subdivided in $\frac{1}{2}$ and $\frac{1}{4}$ cable's lengths; but this offered a complication of divisions, and has since been suppressed. At present, opinion is divided as to whether the scale should be divided into degrees, or the ranges in yards should be marked upon it.

Mode of graduation.

239. The French, who have, probably, paid more attention to this subject than any other nation, have adopted the system of marking the scale for the ranges in cable's lengths, as determined by experiment for each charge. This requires from the captain of the gun no knowledge of ranges; he is solely required to set the scale at the division indicated for the estimated distance, and fire when the head of the tangent, the front sight, and object are in line. The objectors to this system assert that this requires a distinct division of the scale, for each class of guns, and each charge for the same gun. The first objection is common to all systems, since the distance between the sights is different from each class. The second objection is met by the method of marking the scale, hereafter indicated.

The graduation of the tangent for degrees, requires no consideration of the charge, but renders a table of ranges necessary. This inconvenience is certainly very great, as the consultation of a book, or the range board, in time of action, is scarcely practicable.

Plate VII. Fig. 2.

The English have adopted this last system, and from them we have lately borrowed it. We, however, have adopted no tables of ranges; it is, therefore, comparatively a most inefficient machine. En passant, we may say, from experience, that the shape of the front sight (Fig. 3), as now supplied, is not favorable to accuracy, and that the opening in the scale is too great at the bottom.

The method of securing the sights, upon the guns of the new pattern, leaves nothing to be desired in point of stability.

240. The tangent sights most approved by the French, are represented by Plate 7, Figs. 6, 4, and 7. Figures 6 and 4, represent the ordinary Hausse de

Jure, which is to be admired for its simplicity and stability. It consists of a wrought-iron scale, one inch and a quarter in width, and three-sixteenths in thickness, sliding in a brass case firmly screwed to the breech of the gun: this scale is divided on each face by a strong line down the centre; the right edge of one face is divided by notches, indicating the elevation to be given at the several distances with one-third charge, and a solid shot; the left side corresponds to the required elevations with a charge of one-fourth. The opposite face is graduated for ranges with shells. A thumb-screw retains the scale at any elevation. The shape of the head of the scale, is that which experience has proved to be most convenient.

Mode of graduation.

Figure 7, represents the modification of Captain Merme, for correcting the error incident to the trunnions being out of the horizontal plane (Art. 249.) He describes, upon the extremity of the tangent scale, an arc of 20° (10° on each side of the centre line), described with a radius equal to the mean between the maximum and minimum elevations which can be given to the tangent; the front sight is also to be divided into degrees, with a radius equal to its height. This sight permits us to aim in the vertical plane, notwithstanding the inclination of the trunnions; but to do this, it is necessary for the captain of the gun to determine, at the instant of firing, which division on the head of the tangent is in the vertical plane passing through the axis of the bore. At sea, during an action, he has seldom time or presence of mind sufficient to determine this point. This system has not been adopted, nor does it seem to be required for broadside guns, since the lateral deviation is scarcely appreciable. With bow or stern guns, in chase, a correction should be applied: thus, at 1,000 yards, the ship heeling 10°, the

Merme's sights.

lateral deviation will be about 6 yards; we should, therefore, aim at the weathermost part of the hull of the enemy.

Other modes of ascertaining the elevation.

241. Various other methods of procuring the required aim in elevation, have been proposed. Figures 8, and 9, represent dispart, or front sights, with which the required elevation is given by moving an index downwards from 0°: it is evident, that by this arrangement the elevation cannot exceed the angle of sight. Sir William Congreve invented a sight, consisting of a long metal straight edge, having a ring with cross-wires at each extremity; one end was fixed at the reinforce, and the other was susceptible of elevation in a vertical plane. This arrangement offered certain advantages, but the liability to injury and want of the stability necessary to withstand the shocks produced by firing with heavy charges, has condemned it. A side scale, or wooden arc placed upon the steps of the carriage, is sometimes used in connection with a pendulum. By the assistance of the scale, the axis is placed at the required inclination with the deck, and the pendulum shows when the latter is level. Marking the quoins, trunnions, etc., are means occasionally resorted to as methods of determining the required inclination.

CHAPTER IX.

EXAMINATION OF THE CAUSES OF INACCURACY OF FIRE.[1]

Effects of the rotation of the earth.

242. In treating of the causes of inaccuracy, we will first consider the projectile as perfectly spherical and homogeneous, and briefly notice the effects of the motion of the earth upon its accuracy of flight, when projected at an elevation, and the plane of the trajectory making any angle with the meridian. The deviations due to this cause are too slight to be regarded in practice, but a notice of their existence is necessary to complete the subject.

243. The first consideration is, when the projectile, being at a height above the surface of the earth, is left to the action of gravity, so that it will commence to fall vertically. The velocity of the earth at the point of departure being greater than at the foot of the vertical, it follows, that when the body reaches the surface it should deviate from the foot of this line to the east, or towards the side of the true motion of the earth, and that there will be no deviation in the plane of the meridian. This has been experimentally proved, by letting bodies fall in the shafts of deep mines, the deviation observed, taking into consideration the resistance of

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[1] Vide Poisson—Recherches sur la Mouvement des Projectiles dans l'air. Thiroux—Instruction d'Artillerie, Art. Des Deviations.

Effects of the rotation of the earth.

the atmosphere, agreeing, within a small fraction, with the results of calculation.

244. When the projectile is thrown vertically upwards, with a given velocity, it is evident that during the time of its ascension it should deviate from the vertical towards the west, or to the side contrary to the rotation of the earth. It would, therefore, appear to follow, that during its fall it should approach the vertical, and fall at the point of departure; but this is not the case. For, let A′ be the position to which the point A has moved during the time of the upward motion of the projectile; that the latter should return to A′, it would be necessary that it should have reached B′ in the prolongation of the radius A′O, and that this should happen, it must be capable of describing the arc B B′, whilst A describes A A′; but the projectile having but the velocity of the point A, cannot reach B′, but only b; therefore we have Bb = AA′, and the projectile will fall to the *west* of A, in the opposite direction to the rotation of the earth. The amount of this deviation, slight in itself, varies with the resistance of the atmosphere.

Plate I. Fig. 14.

245. If the projectile is fired at an elevation, the effects of the rotation of the earth on its motion will be,—first, an increase or decrease of range, its extent depending on the range and time of flight; second, a horizontal deviation, composed of two distinct parts. One of these partial deviations is independent of the direction of the vertical plane of fire; it is always to the right of the target. In this latitude, we may consider it as the principal effect of the rotation of the earth, and its value is easily ascertained.[1] This deviation is towards the *south*, when we fire towards the

[1] Recherches sur la Mouvement des Projectiles, p. 6.

east; towards the *north*, when we fire towards the *west:* it therefore follows, that to be more certain of striking the target, we should aim a little to the left. The horizontal deviation will be a little less, and towards the *east*, when we fire towards the *north*, and a little greater, and towards the *west*, when we fire towards the *south*. A thirteen inch bomb, fired at an elevation of 45°, and a range of 4,000 yards, would deviate from 5 to 10 yards. Effects of the rotation of the earth.

246. These deviations vary with the latitude of the place of experiment. At the equator, and when we fire in its plane, the horizontal deviations vanish, whilst the increase of range and time of flight attain their maximum. In high latitudes, on the contrary, it is the deviation which approaches its maximum, and the increase of range which diminishes: at the pole, the horizontal deviation, which is at this point the same for every direction of the vertical plane of fire, is about one-half greater than at a mean latitude. There is no increase of range, or time of flight, at any place when the fire is directed in the plane of the meridian.

247. We have heretofore supposed that the line of sight, the axis of the gun, and the trajectory, were in the same vertical plane; but in reality, this is seldom the case; for the projectile does not always follow the direction we would wish to give it, but deviates more or less from the target at which we fire.

248. Deviations are produced by four principal causes: 1st. By a faulty disposition of the line of sight; 2d. By the enlargements which exist in the bore of the gun; 3d. By the irregularity of the projectile, its want of homogeneity, and the motion of rotation which it takes up around an axis more or less oblique with respect to the vertical plane of fire; 4th. Causes of deviation.

From the influence of the wind. We will proceed to examine successively these causes of deviation.

When caused by the position of the line of sight.

249. The line of sight may be improperly placed, and situated out of the vertical plane, either in consequence of the construction of the gun or its carriage, or by the effect of the inclination of the plane upon which it is placed. In these two cases, the line of fire maintaining a fixed and determined position with respect to the axis of the gun, and the vertical plane of fire, the deviations are constant for equal distances and equal inclinations, and it becomes easy to correct them after a few trials.

250. When the trucks of the carriage are not level, the axis of the trunnions is inclined towards the low-

Plate I. Fig. 14.

est side, and the line of sight, M O, traced upon the piece, is thrown towards the same side, and does not pass through the most elevated points of the breech and muzzle. Suppose that the right truck is lower than the left, and let M N be the horizontal trace of the plane of fire; the line of sight, which, in its true position, would be projected horizontally on M N, falls on M′ N′; for, it is evident that the line of sight, whatever may be its position, must pass through the point O, the apex of the cone formed by the lines generating the surface of the gun, and take the position M′ O N′, which, beyond the point O, leaves the plane of fire to the right. We therefore perceive, that if we direct the line of sight M′ O N′ at the target, the shot will deviate to the right of the target—that is, towards the side of the lowest truck.

In the second place, if we project the line of sight on the vertical plane of fire, this line, which no longer occupies the most elevated points of the breech and muzzle, takes the position M′ O, and gives us an angle of sight, M′ O P, smaller than we would wish to em-

ploy; consequently, the shot will strike too low, if the elevation of the gun has been properly calculated; but the difference will not be appreciable, unless the inclination should be very great.

Extent of lateral deviation.

251. These deviations will increase with the elevation of the gun and its distance from the target. To give an idea of the extent of these deviations, we will suppose the plane to have an inclination of 10°, that the distance of the target is 900 yards, and the elevation 6°; the lateral deviation will be 6 yards, and the shot will strike too low by about 20 inches; if the inclination is but 5°, the lateral deviation is reduced to 3 yards, and the fall to five inches.

We have, then, the following rules: Point a little above the target, and towards the side of the elevated trunnion, and make these corrections proportionally greater as the distance of the target and elevation of the gun are increased. It is evident, that if the trucks of the carriage are not of the same height, or the piece is not carefully sighted, the effect will be the same as if the plane upon which the trucks stand is inclined, and that we must employ the same means to correct it.[1] With broadside guns, the correction can never be required, but it becomes of importance with bow or stern-guns, when heeling over in chase. The correction for elevation is evidently very small, even in extreme cases, and the lateral deviation, in general, not very great.

Deviations caused by the enlargements.

252. Other deviations are produced by the lodgment and enlargements of the bore, which exist in all guns which have been long in service.

The calibre of the gun being greater than the dia-

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[1] The loss of elevation = versed sine of the angle of heel.

Deflection is as sine of the heel with the height of the tangent scale, as radius.

Deviations caused by the enlargements.

meter of the shot, it follows that the latter, in bounding along the bore, produces cavities, which, after they have reached a certain depth, destroy all the accuracy of the fire; for the ball, being deflected to the side opposite to that where it last struck the side of the bore, is thrown to the right or left, above or below the direction of the axis, depending upon the last shock; and as the circumstances of the shock of the projectile against the sides of the bore may not be the same at each blow, it follows that the fire loses all precision, since the angle of departure, and consequently the deviation, varies at each round by the effect of the enlargements. It is evident, that the windage greatly modifies the angle of departure, even when there are no enlargements, and that the differences from one round to another increase with the windage.

253. Besides the preceding effects, the gun having motion around its trunnions, may be assimilated to a pendulum, which has been struck by the ball, and may by the shock raise or lower the breech, which will affect the angle of departure.

Deviations caused by want of sphericity.

254. The deviations which result from the imperfection of projectiles are very irregular, and can only be diminished by rifling the bore; but as this means cannot be used for cannon, we endeavor to perfect the projectiles as much as possible, that the deviations may become less, and the fire more exact.

Let us examine the deviations which may occur, and the causes which induce the departure of the projectile from the vertical plane of fire, and make the trajectory a curve of double curvature.

255. One of the causes which principally affect the accuracy of fire is the motion of rotation which the projectile acquires.

The inflammation of the charge beginning at the

upper part, the first gases formed act upon the upper part of the projectile, whilst the lower part is pressed against the bottom of the bore by its weight and the pressure of the gases; therefore the resultant of the action of the gases being directed in the axis of the gun, will act upon the projectile at a point above its centre; consequently the projectile will rotate from above downwards. The motion of rotation produced by this cause is never very violent if the projectile is perfectly spherical and homogeneous; but other causes may greatly affect the motion of rotation.

Deviations caused by want of sphericity.

256. When the projectile is not perfectly spherical, or, being spherical, is not homogeneous, the centres of gravity and of figure do not coincide; let G represent the centre of gravity, and C the centre of figure of the projectile; the force of impulsion, being applied to the mass, passes through the centre of gravity, and the resistance of the atmosphere to the centre of figure C, it follows that these forces, which are not in general directly opposed, have a tendency to generate a motion of the centre of figure around the centre of gravity, the effect of which will be to render the resistance of the atmosphere more or less oblique with respect to the impulsive force, and to produce a greater or less deviation.

Plate I. Fig. 21.

257. Independent of the motion of rotation which the form of the projectile and the respective positions of its two centres tends to establish, every shock or blow against the side of the bore necessarily occasions a motion of rotation. Thus, if the projectile strikes against the side of the bore at A, it necessarily loses a portion of its velocity at the point A by the effect of the shock, whilst the effect of the charge continues to act, tending to increase the velocity of the opposite side of the projectile B, and consequently force it to

The influence of the rotation.

Fig. 16.

The influence of the rotation.

rotate about the point A. Since each of these shocks gives rise to a motion of rotation, these motions modify and destroy each other in such a manner that the final rotation depends on their combination.

This motion, which takes place even when the projectile is perfectly spherical and homogeneous, occasions a deviation which carries the body towards the side opposite to the motion of rotation. Let us suppose the projectile perfectly spherical and homogeneous, and turning from right to left upon a vertical

Fig. 17.

axis, A B passing through its centre of gravity G, which we have supposed to coincide with its centre of figure: it is evident that the air is condensed by the anterior hemisphere of the ball, and rarefied in its rear; but the resistance being tangent to the surface, and manifested contrary to the rotation, this resistance will be directed from left to right on the anterior surface, and from right to left on the posterior hemisphere; the friction being proportional to the pressure, it is evident that the first resistance will be the greater, and the projectile, obeying its action, will be directed to the right.

By applying the same reasoning, the consideration of any other position of the axis of rotation will present no difficulty.

258. We must, however, observe that the deviation due to this friction is only appreciable in the first instants of the motion of the projectile, either because its velocity is rapidly diminished, or rather that the mass of condensed air before the projectile having acquired a certain velocity, exercises a more feeble effect; and experiment demonstrates, that a second cause of deviation operates which modifies, and may even destroy and replace the first, according to circumstances of the motion.

Deviations due to a want of homogeneity.

259. Projectiles which are perfectly spherical, but in which the centres of gravity and of figure do not coincide, deviate still more from the moment they take up a motion of rotation ; experiment and theory equally demonstrate the existence of the motion of rotation in this case.

We will examine several particular cases of this motion, leaving out at first the effect produced by the friction of the atmosphere.

260. If the projectile rotates about a vertical axis, the deviation will always be towards the side of rotation. That is, if the projectile turns from right to left, for example, it is evident that for all the points situated to the right of the trajectory, the velocity of rotation will be in *conjunction* with the progressive velocity of the ball, but in *opposition* to it for all points situated to the left. We see, therefore, that the sum of the resistances experienced by the right side of the ball will be greater than the sum of those experienced by the left side, consequently the projectile will be thrown to the left—that is, towards the side of least resistance. We must observe that the progressive velocity of the ball diminishing very rapidly, whilst that of rotation continues almost without alteration, the influence of the last cause becomes more and more sensible, and the deviations due to it become greater as the projectile approaches the end of the trajectory.

Fig. 17.

261. We have stated that projectiles preserve the motion of rotation to the end of the trajectory ; this fact is proved by a great number of examples, and we may frequently see upon the practice-ground projectiles which, having lost their progressive velocity, roll upon the surface of the ground by virtue of that of rotation, and appear to have lost all their force ; in this state they are still dangerous ; and if any obstacle

arrests their progress, the velocity of rotation is destroyed, wholly, or in part, by the shock, and then all the force possessed by the projectile is employed in clearing itself, and causing it to describe a trajectory, often of considerable extent.

Case in which the rotation produces no deviation.

262. When the axis of rotation is perpendicular to the vertical plane of fire, and the centres of gravity and figure are in that plane, there will be no deviation, and the rotation will only influence the range.[1] If the rotary motion takes place from below upwards, the rotatory velocity is added to that of progression for the lower part of the projectile, and is subtracted from it for the upper part: in this case the greater resistance is exerted upon the lower part of the projectile, which will have a tendency to elevate it, and augment the range; the reverse will take place when the projectile rotates in a contrary direction.

263. If the axis of rotation, although horizontal, makes an angle with the direction of the motion, and we suppose that it remains parallel to itself, the range will be increased or diminished according to the circumstances of the rotation of the projectile, whether from below upwards or the contrary, but the *deviation* will always be towards the side of the least resistance.

But it is evident that the resistance is greater at
Fig. 19. the extremity A of the axis A B; and as no force retains it in this position, this axis will have a tendency to assume a position perpendicular to the direction of the

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[1] This principle has been consulted in the manufacture and employment of shells, by reinforcing the shell in the vicinity of the fuze hole, and placing that part of the shell uppermost in the gun; this of necessity occasions a motion of rotation, which increases the range, and, it is said, its steadiness of flight. We may, however, doubt the wisdom of fabricating irregular projectiles with the expectation of producing more regular effects.

motion, and, after having been for an instant in that position, it will continue its retrograde motion by virtue of the velocity acquired, and take up a diametrically opposite position A′ B′, which will occasion a contrary deviation, which tends to bring it back to the primitive direction, or to pass it, according to the circumstances of the motion.

Case in which the rotation produces no deviation.

264. The deviation due to the friction of the atmosphere is only energetic in the first moments, and when the velocity is very great. At a short distance its effect is very much diminished; then the projectile obeying the increasing action of another cause of deviation may approach the vertical plane, cut it, recede from it, again approach it and pass beyond it, thus encountering it no less than three times during its flight.

We see generally that each point of the projectile describes a species of epicycloid, A, A′, A″, B, B′, B″, and that the effect due to the resistance of the atmosphere, ought to influence the motion of the centre of gravity in a greater degree as the difference between the two centres increases and gives the trajectory a slightly undulating form. Fig. 18.

265. The motion of rotation gives a means of explaining why a projectile thrown with a greater velocity than a similar one, and at the same angle, 45° for example, has no greater range, and often not so great. For, all other things being equal, it is evident that the greater the velocity of rotation, the more will the mass of air be displaced and condensed, and the greater will be the resistance to the progressive motion; but it is also evident, that in general the heaviest charges occasion the most violent motion of rotation, and when the trajectory is of great length it will be much influenced by the motion. By experiments made in England, it has been proved, that at the angle of 45°, a

Case in which the rotation produces no deviation.

charge of one-fourth the weight of the projectile often gave greater ranges than a charge of one-half. These facts appear to confirm the opinion which has been expressed relative to the retarding effect of the motion of rotation.[1]

The combination of motions which results from the shocks of the projectile against the sides of the bore, and those which are derived from the respective positions of their centres of gravity, and of figure, gives rise to various phenomena; for nothing preserves the position of the axis of rotation, which may be changed by the resistance of the medium, as we have previously explained.

Hollow-shot

266. From what we have previously said, it is evident that hollow-shot will deviate most; their centre of figure being always at a different point from the centre of gravity, partly because of the construction itself, partly by a defect of fabrication, also by the variable position of the charge which they contain.

Nature of the deviating force.

267. The deviations increase or decrease in a greater ratio than the ranges, and whilst the resistance of the atmosphere is continually decreasing as the projectile acquires a velocity in the direction of the deviation, the progressive velocity is rapidly decreasing, and the deviations become proportionally greater. Sometimes the deviating force may be assimilated up to a certain point to the action of a constantly accelerating force; this is in general the case when we deduce the extreme deviations of a projectile from the mean of a great number of rounds.

Fig. 20.

268. If the axis of rotation of the projectile is con-

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[1] Thus hollow-shot, or shell, being in general intended to be used at a distance, lose all the advantage of a great initial velocity, in consequence of the irregularity of the rotary motion given them by a heavy charge.

stantly directed in the trajectory, all its points will describe perfectly symmetrical spirals, and there will be no deviation.

Atmospheric resistance being the sole cause of the deviations which we have just examined, we must admit that the deviations ought to bear a certain ratio to that resistance, and that the largest and heaviest projectiles will have the least deviation, and give the greatest ranges.

Influence of the wind.

269. The effect of the wind upon small projectiles is very slight, but it causes an appreciable deviation in those of larger calibres. We will proceed to determine its effects.

As the velocity acquired by the projectile in the direction of the wind is very slight, we may consider the effect of the wind as a constantly accelerating force, and the deviation will consequently increase as the square of the time during which the motion continues, and also as the square of the velocity of the wind. This supposes that the direction of the wind is horizontal, and perpendicular to the plane of fire, and it is generally admitted that it would not influence the range.

270. We have stated (Art. 257) that the projectile drives before it a mass of condensed air, of which the denser parts are in contact with the anterior surface of the projectile; but it is evident, that the least dense portions of the column of air more promptly obey the action of the wind than those which are in contact with the projectile; consequently the direct resistance is slightly diminished, and the projectile experiencing less resistance towards the wind, has a tendency to take that direction, at least if the direct action is not greatest. In this case the deviation will be towards the wind; there are, therefore, forces which act in contrary directions, depending upon the circumstances of the motion.

If the direction of the wind is oblique, the range will be increased in the ratio of the sine of the angle of incidence.

Influence of the state of the air.

271. The barometric state of the atmosphere may also produce an effect upon the ranges; for we readily admit that the greater the density and elasticity of the displaced fluid, the greater the retardation experienced by the projectile.

Of refraction.

272. The phenomenon of refraction also slightly modifies the range; but these last causes of which we have spoken are scarcely appreciable in practice.

Causes affecting the extent of the deviation.

273. The ranges and deviations of the same gun, fired with the same charge, and at the same elevation, vary more or less, and for reasons difficult to appreciate, so slight are the differences: 1st, with the weight and conformation of the projectiles, and the situation of their axis of rotation; 2d, with the greater or less resistance which the atmosphere opposes to the motion, depending upon its density, elasticity, temperature, &c.; 3d, with the more or less complete inflammation of the charge; 4th, with the shocks or blows which the projectile receives on leaving the gun, by the effect of which the elevation is altered; 5th, with the degree of corrosion of the bore and vent, which induces a loss of gases and a diminution of their impulsive force: these causes of variation will always be less effective as the calibre of the gun is increased.

Effect of the ship's motion on the deviation.

274. It appears, from Experiences à Gavrés, that the motion of the ship exercises but a slight influence on the mean deviations. Experiment also proves that the *extreme* lateral deviations are more than double the mean deviations—they depend on the concurrence of several causes; the deviating force should have its greatest value; it should be horizontal; it should act

on the same side as the initial deviation, which should also be the greatest possible.

Effect of the ship's motion on the deviation.

275. If, however, the mean deviations depend on the deviating force only, it is not true with respect to the accuracy of a single shot; there the influence of the initial deviation appears, and also the skill of the pointer; the influence of the windage is also felt. The initial deviation should increase with the difference of the diameter of the bore and projectile.

The employment of too heavy a charge may also affect the accuracy of fire, particularly when the gun is very light.[1]

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[1] Suite des Experiences à Gavrés, p. 44.

CHAPTER X.

CONCENTRATION OF FIRE.

Definition.

276. By this expression is meant the delivery, at one discharge, of the shot from a whole broadside concentrated to a focus; or, at least, to within a small space on the object fired at; as on a ship, or fort, when a vessel may be running past it.

Advantages to be derived.

277. It must be evident to any seaman that the effect of a given number of shot concentrated on a small space, say twenty feet square, on a ship's hull, must be much greater than if distributed at random over the whole surface. To effect this concentration, so long as the enemy can be distinctly seen, it is only necessary to order the captain of each gun to aim at a given point, such as the space between two ports; but as views of the enemy are seldom attainable in the heat of a broadside action, it is desirable to place at command of the captain on deck, or the officers of division, some means of controlling the fire, that there may be some useful effect corresponding to the enormous expenditure of ammunition.

Facility of concentration.

278. The difficulty of accomplishing this object is not so great as is generally supposed. At any range,

if a fire be concentrated upon so great a target as fifty feet amidships of a ship of the line, her distance in the direction of fire of the directing gun may be doubled, without requiring alteration in the laying of a single gun, or the loss of a single shot. The ship fired at may fall off any number of points; yet, if one of the opposing ships does not shoot ahead or drop astern exceeding half her length, the fire will be efficiently concentrated, without any alteration in the guns or the direction of the ship's head. Facility of concentration.

If the enemy shoot ahead her own length when the fire of the battery is concentrated at 200 yards, it will only be necessary to haul up about a point, without altering a gun, in order to preserve the concentrated fire; if she shoot ahead or drop astern two lengths, about two points and a half; if three lengths, a little more than three points. At 400 yards two points are sufficient when either varies her position three lengths.

279. The means proposed for accomplishing this end have generally required the adoption of a slide or other carriage confined to the centre of the port. The following described method, adopted on board the English practice ship Excellent, is simple, and applicable to the present service carriage for broadside guns. Means to be employed.

The triangular board *a*, *c*, *f*, has described upon it an arc of a circle, described from the apex *a* of the triangle as a centre, with any radius, say one foot; the arc *c*, *d*, being divided into points and half points. This board is placed in the rear of the gun, with the base *c*, *d*, upon a line drawn parallel to the keel, and the apex *a* under the centre of the rear axletree of the carriage. As the gun is trained the board is also moved, in order that it may preserve its relative position. The trigger line is held so as to coincide with Plate I. Fig 22.

Means to be employed.

the axis of the gun produced, as *a*, *f*, *h*; when the line covers the given point *f*, the gun will be converged to the distance to which that point *f* may refer. The required point *f* will be different for each gun, and will be more distant from the middle of the base *o* as the gun is more distant from the directing gun. These points may be found by trial, when the ship is at anchor, by mooring buoys at the several distances to which it may be intended to converge the fire of the broadside at any future time, and then by marking on the board the points due to each gun; by this means, it will be found how many points must be allowed at each distance for every gun, according as it may be removed from the converging gun; or, the operation may be effected by calculation.

280. In concentrating any number of guns, it must be understood that the distance is always taken from a certain gun on which the others are concentrated; it is proposed to use the midship gun as the director in each case, because its training is generally equal, both forward and aft.

Calculation of the angles.

281. To calculate the angle for concentrating on the beam: Divide the distance (in yards) from the centre of the midship port to the centre of the port for the required gun by the distance from the object (also in yards), and we obtain the natural sine of the angle. The nat. sine differs so little from the nat. tangent that the difference is unimportant.

Plate I. Fig. 25.

Ex. 1. Let the distance be 200 yards, and the distance between the centre of each port 4 yards, then $\frac{4}{200} = .02$, the nat. sine of 1° 9′ for the gun at A before, and B abaft the midship gun M.

Ex. 2. $\frac{8}{200} = .04 = 2°\ 17'$ for C and D.

282. To concentrate on the bow or quarter, with the gun extreme trained forward or aft: Find the

angle that the midship gun at M makes with the keel, and with this angle and the two sides, AM MC, find M A C, from which subtract 90° for the angle of training of A the gun next forward. Calculation of the angles.

Ex. Let the midship gun be trained forward 37° 30′, the distances as before. Fig. 26.

37° 30′
90

52 30 = Angle between M and the keel.
180

2|127 30
63 45 = ½ sum of the other two angles.

Then by the theorem:

Sum of the sides : Difference of the sides = Tangent ½ sum ang. : Tangent ½ diff. ang.

We have:

204	:	196	=	Tangent. 63° 45′	:	Tangent. 62° 49′	45″
						63	45	
208	:	192	=	„		126	34	45
212	:	188	=	„		90		
				Angle required,		36	34	45

Then by adding, as above, the distance between the ports to the first term, and subtracting it from the second for each successive gun, the angles may be readily found for all.

283. Concentration should not be attempted beyond 400 yards, nor when there is much heel; but when the enemy is close aboard, and concealed by smoke from the view of the men upon the main or lower decks, this method gives the commanding officer on deck the power of controlling the fire of every gun, separately or simul- Limit of distance at which it should take place.

Limit of distance at which it should take place.

taneously, by ordering the gun trained to the required number of points forward or abaft the beam; and, if by the helm the directing gun is kept bearing on the enemy, every shot must take effect, and at or near the focus.

CHAPTER XI.

THE EFFECTS OF PROJECTILES.

Probability of striking the target.

284. With any species of gun the probability of reaching the object increases as the piece is of greater calibre, the trajectory less curved, and, if the target is of such dimensions as to surpass the extent of the mean variations of several successive rounds, fired as nearly as possible under the same circumstances.

The variations we observe are either lateral deviations or differences of ranges. These last are the most important, as we have in general a target of considerable extent, but of limited height, and the difficulty of accurately estimating distances greatly diminishes the chances of attaining the object. It is therefore necessary to pay great attention to the first few rounds, that we may have a means of correcting a faulty estimation of the distance, although we cannot attain the same accuracy as when firing from a fixed battery.[1]

Ricochet firing.

285. When the sea is smooth, ricochet firing can be resorted to with great success, since by it the chances of striking an object are more than doubled,[2] and the

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[1] Vide Art. 274.

[2] "Sur 180 boulets tires de plein fouet contra un but placé à neuf encablures, aucun n'a atteint le but, et sur le même nombre de boulets tires horizontalement, 36 ont touché le but par ricochets."—*Piobert.*

Ricochet firing.

ball of a 24, for example, will penetrate the side of a ship of the line at 600 or 700 yards after a ricochet.

The species of ricochet firing best adapted to the sea-service is that at angles not greater than 2°; the shot will rise at greater angles, but the practice can scarcely be termed ricochet firing. The great object in view is to keep the shot as close to the surface of the water as possible, and the smaller the angle of elevation the better is it effected: with a charge of $\frac{1}{3}$, a 24 at 1° will range 2500 yards, its height at the first curve but 21 or 22 feet, going nearer the surface at every bound; and if it is kept within six feet of the surface at the last bound, it will penetrate the side of a small craft, and sink boats at the extremity of the range. The heaviest charges should always be used, as the ball is much retarded by its grazes, and it would be more prudent to submit to a few shot bounding over the object than to see them useless if they hit it: to practice it in perfection, the water should be perfectly smooth.

This method of firing is particularly useful against steamers, and their uncovered crews; a great portion of their machinery is necessarily exposed, and liable to be destroyed by a ricochet shot plunging below decks at the extremity of the range; the paddles are also easily destroyed, if struck: by this means steamers are deprived of the greater part of their advantages during calms. It is important that the guns nearest the water line should be used, as it is found that they always give the longest range; it might, therefore, be advisable, in some cases, to heel the ship by running in the opposite guns. An advantage is also gained by firing en ricochet *with* the wave rather than against it; and it has been observed that with a ripple or swell diagonally across the line of fire, the shot is frequently

deflected towards the end of its flight, so that its course is at a right angle with the initial direction.

Penetration.

286. The penetration of shot is the primary consideration in measuring the relative effects of different classes of that species of projectile. Solid, or hollow shot, must necessarily penetrate to produce injury; but with shells, that momentum which will just penetrate the outside planking will produce the most disastrous results.[1]

When the projectile has reached the target at which it has been fired, its effects will vary with its hardness, its mass, and its striking velocity; we ought to give it these properties to such a degree as to render it capable of producing the required effects.

It is also required to produce different effects; to pass through an obstacle and destroy bodies beyond it, to overturn it, to destroy it, to separate itself into pieces to cover a greater extent of surface, or to carry incendiary composition to set fire to objects which cannot be approached.

Influence of the hardness of the projectile.

287. The hardness of a projectile always favors its penetration into a body; it should increase with that of the obstacle: if it is not sufficiently great with respect to this last, it is flattened at the instant of contact, and presents a greater surface perpendicular to the direction of motion; it consequently experiences a greater resistance, and penetrates to a less depth; this effect is sensible, even against water, as is shown by experiments upon the penetration of musket-balls in water at different distances, and consequently with different striking velocities.

When the projectile is of so hard a material that it

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[1] By experiments at Gavrés, a projectile will not lodge in an oaken target, unless its penetration equals its diameter.

does not alter its figure, the penetration always increases with the velocity, and is proportional to its diameter and density; it depends more on its velocity than its mass. When the velocity of the projectile is very great, the time of penetration is so short that the particles of the body which opposes its motion are destroyed, before they have time to react on the adjacent particles; and the body is penetrated without being sensibly shaken.

Influence of the velocity.

288. When a projectile is fired with considerable velocity against wood, it penetrates to a great depth, leaving but a small hole; with a less velocity it shakes and destroys the whole mass. If, then, the projectile is intended to shake or overturn an obstacle, it should possess but a low velocity; it will also be advantageous to give it a considerable diameter and density.

The effect of projectiles upon wood also varies with the species and the direction in which they penetrate. If the wood is oak, and is struck perpendicularly to its fibres, a part of the elastic fibres are crushed, the others bend under the pressure of the projectile, but return to their former position after its passage, so that the hole made by a ball of 24 may be stopped by a small plug. If the wood is pine, the fibres of which are alternately soft and hard, the first are compressed, and the others do not resume their former position; the hole is, therefore, greater than in oak. If the wood is struck in the direction of its fibres, they are first compressed, then they straighten themselves, but do not close the hole so completely as in the former case.

289. If the projectile possesses a quantity of motion greater than is required to destroy the object which it strikes, we may divide it, so that it may strike a number of objects, and produce a greater effect; each part

having the same velocity as the whole projectile, and but a portion of its mass. This separation may be arranged in advance, as in grape and canister shot; and in this case each partial projectile should receive such a figure as best conduces to its accurate flight; or, the separation may not take place until after its arrival at the target, as with shells in ordinary practice, which are bursted by the ignition of a charge which they contain. Finally, both these effects may be united, as in Schrapnel shell: this shell is filled with musket-balls, and a small charge of powder, which is exploded before the arrival at the target; its pieces are thrown laterally, as with ordinary shells, and the balls which it contains separate a little, and moving with the velocity of the shell at the instant of explosion, cover a considerable extent of surface: these shells are of service against troops in the field, but their advantages have been greatly overrated.

Influence of the velocity.

290. The effect of a projectile varying with the hardness of the substance which it strikes, the resistance which it experiences will increase with its velocity and the hardness of the body struck; if this last is a soft body, the projectile does not experience a resistance sufficiently great to alter its figure; it crushes or separates the parts of the body, penetrates until the sum of the resistances which it meets has exhausted its force, and is checked at a certain depth without having been broken or its figure altered: this depth depends on the mass and velocity of the projectile, and the retarding force of the body struck. In other cases the hardness of the body and the velocity of the projectile may be so great that the resistance which the latter experiences may cause it to be broken.

Relations of the hardness of the projectile and the body struck.

This effect depends not only on the hardness of the body struck, but also on the hardness of the pro-

jectile; thus very hard bodies, as iron, are dinted by the blow of a projectile moving with a low velocity, without affecting the figure of the latter; whilst against lead, the projectile itself is broken, if its velocity is very great.

Effect of impact upon iron.

291. The heaviest blocks of cast-iron are completely shattered by the impact of a shot, even of the smallest calibre, and the pieces scattering in every direction become deadly missiles. In the course of experiments at Metz, in 1834, a block 3 feet by $1\frac{1}{2}$ was split throughout its whole length by the impact of a ball of 24 fired with a charge of $\frac{1}{2\frac{1}{4}}$. Against wrought-iron the shot is broken, and if the velocity is sufficiently great the body is penetrated. The shock developes a heat so great that the pieces cannot be held in the hand, and their blue color indicates that the temperature has been raised to about 600°, the point at which powder ignites. If a loaded shell is struck by a shot, the heat developed may ignite the charge, and cause a most disastrous explosion.

292. The effects of projectiles upon masses of masonry are very different from those produced by impinging upon wood or metals; this material, not being possessed of elasticity, is crushed and broken by a force of impact greatly inferior to that required to produce an effect upon elastic bodies: when a mass of masonry is struck by a shot moving with a high velocity, the particles in the vicinity of the point of impact are crushed, and the shot in penetrating forms a wide-mouthed, funnel-shaped cavity; the shot rebounds from the cavity, and the fragments of masonry are projected to considerable distances: the mouth of the cavity is from four to five times the diameter of the projectile; the interior of the cavity is nearly cylindrical; the depth depends on the velocity of the pro-

jectile and the hardness of the masonry. If the shot strikes obliquely, it ricochets at an angle which depends on the hardness of the masonry and the velocity of the projectile; this was determined by experiments at Metz to be at 20° for a charge of half the shot's weight, at 43° for a charge of one-sixth, the angle of reflection being greater than the angle of incidence, the piece having been placed at a short distance from the wall. Effect of impact upon iron.

The effect of shells against masonry is almost null; they either break at the moment of the shock, or, if fired with small charges, they produce but a slight impression.

For these reasons ships can produce but little effect upon batteries; and if to the want of penetrative force we add the uncertainty of practice, they prove more noisy than dangerous. It is generally admitted that four guns of the calibre of 24 or 18, protected by a wall, and properly served, are equal to a ship of the line; and that it is almost impossible to destroy a fort with ships, even if at anchor: the fire of bombs is still more uncertain; and although it would appear that in the bombardment of forts the advantages are in favor of the assailant, on account of the greater extent of surface exposed, yet the contrary is the case on account of the uncertainty of the pointing at sea: if we approach to a closer distance, the advantages on the side of the assailed increase, unless indeed we can attain a position within the cross-fire of the batteries, where we can in rapidity of fire and number of guns compensate for inferior effect.[1]

293. The greater the calibre of a shot, density, ele-

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[1] The bombardment of San Juan de Ulloa by the French was begun at a distance of 2200 yards: of 302 bombs, only 6 fell within the fort, some of them reaching the city of Vera Cruz—an error of range of 1200 yards.

Influence of calibre.

vation, and initial velocity being equal, the greater will be the range and penetration, and the more accurate the practice.

This will appear evident, when it is considered that the resistance of the atmosphere to shot of different calibres is as their surfaces; that is, as the *squares* of their diameters; whereas the weight of the shot, or power to overcome the resistance of the atmosphere, increases as the *cubes* of their diameters, consequently the remaining velocity of the shot of the higher calibre must be greater, and it will obviously range further than the less shot. It will also penetrate deeper; for, although the penetrations of shot are as their diameters, yet they are also as the squares of the striking velocities.

It is equally obvious that the shot of greater calibre will be less susceptible of deflection from the line of direction; and, comparing the results of extensive practice, it may be confidently asserted that the probabilities of hitting with shot of equal windage and initial velocities at 1000 yards, are as the squares of the diameters, and in a greater ratio, as the range increases: the deviations of shot of the same diameter, but of different densities, are inversely as their density.[1]

Necessity of penetration.

294. Heretofore it has been generally supposed that the principal consideration in Naval Gunnery was to hit the object; latterly, however, the importance of penetration has attracted the attention of artillerists, and, comparing the results of experiments with those of numerous engagements fought at "half pistol shot," we may easily show that this opinion is erroneous,

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[1] Poumet,—Essai sur l'art de Pointer.

and that we are within the limits of accuracy before we attain a penetrating distance.

Required penetration.

295. The thickness of the sides of a line-of-battle ship has been estimated at 30 inches of solid oak, a frigate's side at 20 inches; we must, therefore, estimate the required penetration at least to those depths, particularly when it is considered that ships are seldom so placed that the shot strikes an antagonist at right angles.

It is to be regretted that so little is known upon the subject of penetration at distant ranges, the tables being in general constructed from calculation and observation of the effects of shot at short ranges. The formulæ which represent these results are, however, valuable, inasmuch as they accurately represent the *relative* values of different species of projectiles.

Assuming Hutton's data, and adopting his formulæ, it will be found that shot and shell, to penetrate 30 inches into oak, require to strike the object perpendicularly with the following velocities:[1]

Nature of projectile.	68.	42.	32.	24.
	Feet.	Feet.	Feet.	Feet.
Solid shot	1208	1317	1378	1446
Shell, empty	1376	1501	1572	1647
" filled with powder . .	1354	1477	1545	1620
" filled with lead . . .	1142	1247	1303	1368

The practice at which Hutton assisted appears to have been conducted with the greatest accuracy; he is considered as the highest authority, and all the artillerists of Europe rest on his data and deductions.

[1] Simmons,—Ideas as to the Effects of Heavy Ordnance. The numbers here given are calculated for the shells and shot current in our service.

Required penetration.

296. If we take Robins' practice as more favorable to the penetration of shot, and apply the formulæ, the following table may be constructed :

Nature of the projectile.		Required striking velocity to penetrate.	
		30 inches.	18 inches.
32-pounder	shot	1090	845
	shell, empty	1242	963
	" filled with powder	1222	948
	" filled with lead	1001	799
24-pounder	shot	1144	886
	shell, empty	1304	1021
	" filled with powder	1283	994
	" filled with lead	1082	837

Upon Robins' data with solid 32-pound shot at 750 yards range, an initial velocity of 1800 feet will be required to retain a striking velocity of 1090, which *is* necessary to penetrate 30 inches of oak; this is about the velocity gives by our present full charge and medium windage. Shells or hollow-shot can only be relied on to penetrate as far as 350 yards. A penetration of 18 inches may be obtained at 1200 yards, the required striking velocity being about 850 feet: the leaded shell, with a proportional charge of $\frac{1}{3}$, may be relied on to a range of 2000 yards, the required striking velocity being about 750 feet; but this range will be obtained at the expense of inconvenient recoil and an undue strain on the carriage and breeching; the hollow shot with the charge of $\frac{1}{3}$ the solid shot only to 550 yards, the required striking velocity being about 1220 feet; with even less charges they are often broken in the gun.

297. The accuracy too of the solid shot will be much greater, both on account of its greater remaining velocity, and because the hollow shot, to obtain the

same range with equal charges, must be fired at a greater elevation, since the elevations to obtain the same range will be reciprocally as the squares of their velocities. It is asserted that practice has established that the deviations of shot of different density, but the same diameter, are inversely as their densities.[1]

Advantages of solid shot.

Thus to obtain similar results with hollow and solid shot, it will be necessary greatly to increase the charges with which the former are projected, consequently increasing the expenditure of powder. The only advantage, even at the closest ranges, in using the hollow shot of the same calibre, arises from the less exertion necessary in handling it, in transmission to the gun and in loading; there can be little benefit in using hollow-shot under any circumstances.

Col. Paixhans, himself, while advocating the use of hollow-shot, demands the increase of calibre, saying, "we may obtain the same ranges with a greater calibre, and perhaps the explosion of the shell may compensate for its inferior accuracy;" from which we may infer, that he never intended to project uncharged hollow-shot, at least, except the gun was of great calibre; if, however, the shell be loaded, its destructive powers must be very great; the only penetration necessary or even desirable would be to the depth of the diameter of the shot (Art. 286). To this depth into oak 8-inch shells may be expected to penetrate at a range of 1000 yards, or a 32 at 850 yards, if charges of $\frac{1}{3}$ the solid shot are used, the required striking velocity being about 680 feet.

By a reference to Table IV. we see that we are within the limits of accuracy at distances greatly exceeding those at which an effective fire can be sustained.

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[1] Coste,—Des deviations du tir des projectiles.

298. Simultaneously with the introduction of hollow-shot and loaded shells an increase of calibre took place; this increase became necessary to compensate for the inferiority in accuracy and penetration of the shell. Economical considerations suggested the plan of reaming up guns to a greater calibre, but this practice has not been followed in our service; a better distribution of the metal has been made in the new guns by reinforcing the breech and lightening the muzzle, to give both greater strength and projection from the port.

This form was suggested by the late Colonel Bomford of the Ordnance Corps, but was neglected until brought to the notice of the French government by Colonel Paixhans,as suited to the horizontal projection of loaded shells; since which period the howitzer cannon has been introduced into the navies of every nation.

299. The 8-inch shell gun has been adopted in our own and the English service, as the greatest broadside calibre; it corresponds in weight with the long 32, and displaces a portion of the latter on the main decks of ships of the line and frigates. Although slightly inferior in destructive effect to the French shell gun of ·22^{m}. (8·67 in.), yet it is probably near the limit of convenient handling, and may in rapidity compensate for inferior range, accuracy and penetration.

It has not been deemed expedient to introduce more than eight upon the main or lower decks of ships, or four upon the decks of sloops; a certain proportion of the ammunition for all classes of guns, consisting of shells, fixed, fused, and boxed up before being placed on board.

Effects of hot shot.

300. Hot shot, although seldom resorted to from ships, yet may be available from steamers, which have

conveniences for heating them, as their range will be greater, and the practice more accurate than with shells. The penetrations of hot and cold shot are equal; but the less the penetration of the hot shot, the sooner will its effects become evident: if the penetration be too great, the aperture closes from the elasticity of the wood, and prevents the admission of the exterior air.

Effects of grape-shot.

301. Some experiments made on board the English practice-ship Excellent upon the range, penetration, and spread of grape, produced the following results: the round and grape ranged closer together, when the round was put in first, but the gun required a greater elevation, because the grape retarded the round; the grape ranged tolerably well together to 300 yards; at that distance the penetration into oak was from 2 to 3 inches: with double-grape the range, spread, and penetration were nearly the same.

CHAPTER XII.

GENERAL PRACTICAL DEDUCTIONS FROM THE PRECEDING CONSIDERATIONS.

Atmospheric resistance.

We here present in a condensed form the most important principles which have been discussed and established in the preceding chapters.

302. The resistance of the atmosphere to shot of different diameters, with equal velocities, is very nearly in the proportion of the squares of their diameters, or as their surfaces; if the shot are of the same diameter, but of different densities, the effects of the retarding forces will be inversely proportional to their densities.

303. The velocities decrease as the distances increase; this is caused by the resistance of the atmosphere to the shot's motion; the resistance is for shot of equal diameter and density in a somewhat higher ratio than the squares of the velocities.

304. The velocity of the projectile increases with the charge to a point peculiar to each gun; but by further increasing the charge, the velocity is gradually diminished; yet the recoil is always increased by an increase of the charge.

305. When shot of different weights are fired with the same charges of powder, the velocities communi-

cated to them are nearly in the inverse ratio of the square roots of their weights. By using shot of a heavier metal than iron, lead for instance, or shells filled with lead, the momentum of the shot discharged with the same charge of powder would be increased in the ratio of the square root of the shot's weight; which would both increase the force of the blow with which it would strike, and also the extent of the range. Atmospheric resistance.

306. Heavier shot with less velocity, within certain limits, will range farther than lighter shot of equal calibre and greater velocity; thus if shot and shells are fired from guns of equal calibre with equal charges, the shell will acquire an initial velocity greater than the shot in the inverse ratio of the square roots of their weights; but since the resistance of the atmosphere, the velocities being great, is in a higher ratio than the squares of the velocities, it follows, that the velocity of the shell will decrease more rapidly than that of the shot; there will consequently be a spot at which their velocities will become equal, and since from that point the shot is less rapidly deprived of its velocity than the shell, the former will attain the greatest range.

307. By firing the charge in different places, separately or simultaneously; by hard ramming the charge; by varying the weight of the gun to lessen the recoil; or even by stopping the recoil entirely, no sensible change is produced in the velocity of the shot.

308. The time required by the shot or shell to describe the trajectory, is equal to the time in which a body falling freely would descend from the highest point of the curve described by the projectile; the time of flight is nearly proportional to the range, the gun and elevation remaining the same. Of the time of flight.

309. Very little advantage is gained in point of

Of excessive charges.

range, by increasing the charge more than is necessary to reach the object; the velocities given by large charges being very soon reduced to an equality with those given by moderate charges; those, for example, given by half the shot's weight, are reduced to an equality with those of one-third, after passing through about 200 feet.

Of the length of guns.

310. Very little benefit is derived from increasing the length of guns; the velocity given by long guns of 22 calibres being reduced to an equality with that from short guns of $15\frac{1}{2}$, with similar charges, after passing through the following spaces:

With	$\frac{1}{2}$	the shot's weight,	about	285	feet.
"	$\frac{1}{3}$	"	"	200	"
"	$\frac{1}{4}$	"	"	150	"
"	$\frac{1}{6}$	"	"	115	"

Of the use of wads.

311. The use of wads over the ball does not increase the force of the charge or the extent of range; but a hay or junk wad is productive of decided injury in respect to accuracy.

Of the vent.

312. The loss of force by the regulated vent, with ordinary charges, is inappreciable.

Of percussion primers.

313. The use of percussion primers produces no sensible increase of force in cannon charges.

Of the size of grain.

314. For powder of the greatest density, and highly glazed, the force is greatest in small grain; with the service powder the effect is greater in mixed grain, as required by regulation; in general the greater the density the finer the grain.

Of the windage.

315. The regulation windage, ·15 in., causes a loss of one-third the force of the charge; the loss is relatively greater as the density of the powder increases.

316. The ranges of shot of all calibres vary more

when the pieces are fired under small angles of elevation, than under large angles.

317. With different velocities to produce the same range, the angles of elevation will be nearly inversely proportional to the squares of the velocities.

Accuracy.

318. The accuracy of shot projected at different elevations, all other circumstances being equal, will be as the angles of elevation reciprocally, unity being added to the number of degrees.[1] In the case of field guns, where the range and accuracy only are required, the range and precision of shot are in a greater ratio than their weights, or than the cubes of their diameters. At sea, where penetration and the size of the orifice are of the greatest importance, the *general effect* is with equal velocities as the fifth powers of the diameter.[2]

319. The chances of hitting any object diminish with the length of bore of the gun, the windage, the diameter and density of the projectile, the charge of powder and the elevation; with shot of equal density, windage, and initial velocity, practice has established that the probabilities of hitting at a range of 1000 yards are as the squares of the diameters of the projectiles; the deviations of shot of different densities but the same diameters, are inversely proportional to their densities.

Penetrations.

320. The penetrations of shot of the same diameter and density, with different velocities, are nearly as the squares of the velocities; shot of different diameters will penetrate to depths proportional to their diameters; if of the same diameter but of different densities they will penetrate to depths proportionate to their densities.

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[1] Coste. Des Deviations du tir des Projectiles.

[2] Ideas on Heavy Ordnance, p, 68.

In firing into masses of timber, that velocity which can but just penetrate, will occasion the greatest shake and tear off the greatest number of and largest splinters; consequently an advantage is gained in close action by reducing the charge.

CHAPTER XIII.

ON THE ARMAMENT OF SHIPS OF WAR.

Opinions formerly entertained.

321. In discussing the armament of ships of war, a sketch of the opinions formerly entertained upon the subject may elucidate the reasoning of the advocates of the present system.

In the early days of naval history, it was the practice to crowd into a ship as many guns of moderate calibre as could be conveniently worked, relying upon the results arising from a rapid fire of numerous pieces. In those days ships were of the slightest scantling; for these light pieces being distributed over the whole body, did not require the heavy frames of the present day to support them. As ships became larger and the scantling increased, the penetration of shot from these light pieces became insufficient to produce a serious injury, for we read of engagements lasting for three days, whilst with our present armaments, half an hour of close combat would necessarily reduce a ship to a sinking condition. The fire, however, appears to have been principally directed upon the *personnel* of the enemy; and thence arose the necessity for those unsightly excrescences, the forecastle and poop, from which commanding positions an effectual fire could be

maintained upon the decks of the enemy preparatory to boarding.

As the knowledge of the art of war increased, the seamen, who were at first employed to bring the ship into close action, became the principal actors. More attention was paid to manœuvring, and their attention was directed to disabling the ships of the enemy. The ships were also larger and less manageable; consequently the favorite manœuvre of boarding was more difficult, and it became necessary to reach the enemy through their defences, by employing shot of sufficient penetrative power to pass through the side opposed.

The long 18 was therefore adopted by the British for the principal battery, as possessing all the requisite qualities. This gun being too heavy for the upper decks of ships of the larger class, and for the armament of smaller vessels, the carronade, of a higher calibre and little proportional weight, was substituted for it. This mixed armament was sufficiently well adapted to the system pursued by them in their naval combats, of closing the enemy to engage at pistol shot. These tactics, if tactics they may be called, were generally successful in single ship actions; but no important advantages were gained in general engagements until after Rodney practised successfully the manœuvre of breaking the line, by which the opposing fleets were enabled to close, and the British to assume their favorite position, "yard-arm and yard-arm."

Advantages of calibre.

322. The advantage of a high calibre had always been recognized by the French, and from them we adopted it in the ships built after the close of the war of the revolution. A wise foresight had induced our government to give these ships greater tonnage and heavier frames than any ships of their class then afloat, thus enabling them to bear heavier batteries and to sustain

greater injuries before being disabled. The war of 1812 with Great Britain produced the results which were to have been anticipated. Our ships were uniformly victorious over those of the same nominal force, and our enemies were not backward in attributing their defeats to the proper cause. That we were in general superior in force, every candid man must admit; but, at the same time, we see a commensurate disparity in loss.

The practical results of this war led to a general increase of calibre throughout the navies of the world. But, granting that the most effective battery is composed of guns of the greatest calibre, projecting with the maximum velocity shot of the greatest possible density, there is a practical limit, beyond which we cannot pass without causing a diminution of effect. We will therefore proceed to establish the conditions which determine the selection of a battery for a ship of war.

Conditions to be fulfilled.

323. In building a ship, or adapting a battery to one already in service we must be governed by three principal considerations: the total weight she is to carry, which depends upon her tonnage and stability, the service for which she is destined, and the individual weight of the guns.

Total weight.

324. As a vessel of war must necessarily carry a large quantity of provisions, to sustain the crew required to work the battery, in assigning the entire weight reference must be had to her tonnage and capacity for stowage, that she may not exceed the requisite draught for sailing and manœuvring to the best advantage. We must also pay some attention to her stability; for, of two ships of equal tonnage, one is frequently more stable, and, consequently, able to resist the straining effects of a heavier battery.

325. The individual weight of any gun must depend

Individual weight.

upon the scantling of the vessel; for, it is evident that, although the total weight may not exceed her capacity, yet the straining effect of the heavy gun is greater than that of a number of smaller pieces, the weight of which is uniformly distributed over the frame. It is generally assumed that the number of men required to work the battery is proportional to its weight; but proportionally more men are required to work the lighter than the heavier gun.

326. The service for which the vessel is designed must also have an important bearing upon her armament. A small vessel, being especially designed to cripple the commerce of the enemy, should be armed, with reference to that design, with one or two pieces of great proportional weight; such guns having the greatest range, and being, consequently, best adapted to cripple a vessel chasing, or of which she is in chase. The remainder of her armament may consist of proportionally light pieces, with a view of maintaining a rapid and effectual fire in close action, and repelling boats.

Class of vessels.

327. The larger classes of vessels, such as frigates and ships of the line, being often drawn into bombardments of forts, as well as single combats, manifestly require a mixed battery; for against masonry only the larger calibres, fired with the maximum velocity, are serviceable; and in close action the quickness with which proportionally lighter guns can be worked, may mainly influence the result; consequently, for these vessels, guns of different weights may advantageously be placed in the same battery.

328. There are two methods of lessening the total weight of the armament of a vessel: the first consists in arming her with guns of a smaller calibre; but she will then lose a portion of her military force. The

second is, to diminish the individual weight of the guns, retaining their number and calibre.

The second mode of diminution is attended with serious disadvantages. The thickness of the metal cannot be reduced, if we retain our present charges of powder, for it is at present no greater than is necessary to sustain the effort exerted on the inflammation of the charge. We may shorten the gun; but this brings the muzzle so near the port that the noise, smoke, and sparks, produced by the explosion, annoy and endanger the men at the gun; and the recoil and reaction, if mounted upon any carriage not furnished with a complicated apparatus to check it, would greatly strain the bulwarks and breechings.

If, on the other hand, we diminish the charge, there will be a loss of initial velocity, of range, and useful effect.

Number of guns.

329. The number of guns in a battery is limited by the necessity of leaving sufficient room between them, to allow them to be served without the crews incommoding each other.

Having established the entire weight of the battery, and the number and individual weight of the guns, by attending to the preceding considerations we next proceed to determine the calibre of the gun, consequently its proportional weight.

Calibre.

330. The calibre of the gun is limited by two causes; first, our ability to handle the shot; secondly, the necessity of impressing upon the shot sufficient velocity to produce the necessary degree of accuracy and penetrative force at the extreme range requisite.

It is evident that the fire must be wanting in rapidity, when we are obliged to resort to machinery to raise the ball to the muzzle of the gun. The greatest

Calibre. broadside calibre has therefore been fixed at 68 lbs., and even these are employed in but a limited number.

We must also impress upon the shot high velocity, which has been shown to be essential to accuracy and penetration; but since the velocity of the shot is governed by the recoil of the gun, this can only be done by giving the gun great proportional weight; therefore, the total weight and number of the guns having been determined, we cannot increase the calibre beyond a certain limit.

The advantages of reducing the armaments of all classes of vessels to a single calibre are also deserving of attention.

331. Different opinions are entertained upon the points heretofore enumerated; but the three great naval powers have fixed upon the **32** as the limit combining effect, rapidity, number of guns, and convenience of manipulation. The **42** is advocated by a numerous body, basing their arguments upon the acknowledged superiority of nearly **2** to **1** in respect to accuracy, penetration, and the diameter of the orifice; whilst, for the same total weight of battery, the **32** outnumbers the **42** only as 4 to **3**. It is asserted that they can be served with equal rapidity, thus giving the compound relation of **3** to **2** in favor of the **42**, a ratio greater than that of their respective weights.

332. The introduction of loaded shells and hollow shot into naval warfare rendered a slight modification of the armament necessary. These missiles, not being possessed of sufficient density to be effective, when fired from guns of the ordinary calibres, in accordance with the principle enunciated in Art. **27**, it became necessary to compensate for their inferiority of density by increasing the diameter. This led to the adoption of a mixed armament of shot and shell guns, the latter being

of greater calibre. We have fixed upon a system of placing four of these shell guns of 8-inch calibre upon the lower and main decks of ships of the line and frigates, and the spar decks of first class sloops; the remainder of the battery being composed of 32's of the greatest proportional weight which the vessel will carry.

Steamers, being intended to operate at a distance greater than the broadside range of sailing ships, are armed with one or two pieces of 10-inch or 12-inch calibre, mounted on traversing carriages, commanding an extensive sweep, and affording considerable elevation.

333. The carronade, which formerly occupied the spar decks of all classes of ships, and superseded 6, 9, and 12-pounders, as the entire armament of smaller vessels, has proved, by experience, wanting in all the essentials of a perfect equipment. It has, consequently, been banished from the existing list of armaments, and its place supplied by a smaller number of the 32-pounder of 27 or 32 cwt. Even the first of these is deficient in accuracy, and, with the regulated charge, recoils with extreme violence.[1] For this reason it has been recommended to abandon the use of solid shot with the full charge; and it will be interesting to inquire at what point, with equal recoils, the effects compensate.

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[1] The recoil might and should be moderated by diminishing the diameter of the trucks of the carriage, and with these proportionally light guns it might be expedient to lower the axis of the trunnions.

CHAPTER XIV.

PRACTICAL INSTRUCTION.

NOMENCLATURE OF GUNS, THEIR CARRIAGES AND EQUIPMENTS, AND OF THE IMPLEMENTS USED IN THE SERVICE OF GUNS.

334. *Of the gun.*

The *bore* is the interior cavity destined to receive the charge and direct the flight of the projectile.

The *chamber* is the contraction of the bore at the place of the charge, intended to increase the effect of small charges.

The *slope of the chamber* is the conical surface which connects the chamber and the bore.

The *muzzle* is the mouth or entrance of the bore.

The *face of the muzzle* is the plane which terminates the gun.

The *muzzle mouldings* consist of the *lip* and the *fillet.*

The *tulip* or *swell of the muzzle* is the increase or greatest diameter of the metal towards the muzzle.

The *neck* is the curved surface joining the tulip to the *chase.*

The *chase ring* (or muzzle ring) is a band encircling the gun at the point where the neck and chase unite.

The *chase* is that part of the length comprised between the chase ring and the second reinforce.

The *second reinforce* is the cone extending from the chase to the first reinforce.

The *first reinforce* is the cylinder extending from the first reinforce to the base ring.

The *trunnions*, which are in the second reinforce, are cylinders projecting from the gun, which support it on its carriage.

The *rimbases* are cylindrical masses of metal, which serve to increase the strength of the trunnions and prevent lateral motion on the carriage.

The *vent patch*, in the first reinforce, is a mass of metal in which the vent is drilled, and to which the lock is attached.

The *vent* is the conical channel through which fire is communicated to the charge.

The *base ring* is the band encircling the gun at the junction of the reinforce and the base of the breech.

The *cascable* (consisting of the *base of the breech*, the *ring*, the *fillet*, the *neck*, and the *nob*) is that part of the gun in the rear of the base ring.

The *base of the breech* is the hemispherical portion of the gun in the rear of the base ring.

The *neck* of the cascable is the concave surface connecting the base of the breech and the nob.

The *cascable ring* is a ring through which the breeching is rove, connecting the base of the breech and the nob.

The *nob* is the spherical mass of metal terminating the gun.

335. *Of the gun-carriage.*

Wood work Plate II.

The *cheeks* A (in large carriages composed of two pieces, connected by a *jog* J), are the two principal pieces of the carriage, and support the gun; the cheeks contain *b*, the trunnion holes; *a*, the arch;

Wood work. Plate II.

s s s, the steps, which serve to place the handspikes upon when it is desired to raise or lower the gun.

The *transom* B, unites the cheeks, and preserves them in a vertical position.

The *breast-piece* C, which is in two parts, hinged, slides in between, and is bolted to the cheeks; it strengthens the carriage, and, by keeping the trucks clear of the axletrees, facilitates pointing.

The *outer axletree* D, and the *inner axletree* E, are composed of the *square body* and the *arms*, *d d*. The axletrees connect the cheeks and receive the *trucks* on their extremities.

The *trucks* H I, are rollers or solid wheels, which support the carriage.

The *dumb trucks h h*, support the carriage should the trucks be destroyed, or taken off to moderate the recoil.

The *bed* F, with its *stool k*, is used to support the quoin in ordinary pointing in elevation. When extraordinary elevations are required the bed and stool are removed, and the quoin is placed on the rear axletree.

The *quoin* G, is a wedge of light wood, having a handle attached to its base; it is placed on the bed, and pushed in or out to give the required elevation.

Iron work. Plate II.

The *cap-square*, 3, is a plate of iron which confines the trunnions of the gun in the trunnion holes; it is secured by the aid of the *chin-bolt*, 2, and the *cap-square bolt* and *key*, 1.

The *cheek bolts*, 4, secure the pieces, of which the cheeks are composed.

The *inner axletree bolts*, 5, secure the axletree to the carriage, and assist in consolidating the cheeks.

The *side-tackle bolts*, 6, serve to hook the tackles used in running out and training the gun.

Iron work.

The *train-bolt*, 7, driven in the rear of the axletree, is to hook the train-tackle bolt to in running in.

The *transporting-bolt*, 8, driven in the outer axletree, is to hook the tackle to in transporting the gun from port to port.

The *breast-bolt*, 9, confines the breast-piece in its place, and assists to secure the cheeks.

The *hinges of the breast-piece*, 10, permit the latter to be raised when the gun is secured in the port, thereby permitting the gun to run out farther and occupy less room on deck.

The *transom bolts*, 11, confine the transom in its place and consolidate the cheeks.

The *breeching shackle*, 12, is to take the breeching, and keep it clear of the trucks, being confined by the *pin*.

The *bed-bolt*, 13, is to sustain the extremity of the bed.

The *axletree bands*, 14, prevent the axletrees from splitting.

The *chafing plates*, 15, protect the cheeks from the chafe of the handspike in training.

The *linch-pins*, 16, with their *washers*, 17, prevent the trucks from slipping off the arms of the axletrees.

336. *Of the equipments.*

The *breeching* is a large three-stranded rope, with a *thimble*, 20, spliced into each extremity, and attached to the *shackle-bolts*, 18, by the aid of the *shackle-pins*, 19; it serves to check the recoil of the gun, and to secure it for bad weather; its length should be such as to permit the muzzle of the gun to clear the inside of the port.

The *side-tackles*, of which there are two, are composed of a double and single block, single strapped. The

double block is, during action, to be hooked, point of the hook up, to the *fighting-bolt*, which is placed midway between two adjacent ports. The single block is hooked, point in, to the side-tackle bolt. The length of the fall is three times that of the gun.

The *train-tackle*, similar to the preceding, is hooked with the double block to the train bolt; the single block to a bolt in the rear of the gun.

The *muzzle-lashing* and *frappings* secure the gun in a sea-way, when run in, to take the strain off the side.

The *port-tackle*, in ships of the line, is used to trice up the lower deck ports. It is hooked to a pendant, which passes through the side. The *port laniards*, in other vessels, haul up and secure the *half ports*.

The *seizings* are rope-yarn knittles, blacked, and are used to secure the tackles, &c.

337. *Of the implements.*

The *percussion lock* is secured to the vent patch by two bolts, which pass through it, and are drawn up by nuts.

The *vent stopper* is attached to the lock, and is moved by hand, on or off the vent, as required.

The *front sight* is a piece of metal secured between the trunnions, giving a line of sight parallel to axis.

The *sight* is a slide, moving in a brass case attached to the base ring, and moving in a vertical plane. By the use of this instrument, with the aid of the front sight, we may vary the angle of sight at pleasure, which permits us to aim directly at the object at all distances within the limits of the range.

The *apron* is of lead or copper, and serves to preserve the lock from injury, and moisture from entering

the vent; it is furnished with two *laniards* to secure it to the gun.

The *priming-wire* is of iron wire, sufficiently hardened to be stiff, yet not so brittle as to break by an accidental blow with the rammer; it has a ring at one end, and the other is terminated by a point; it serves to clear the vent and to prick the cartridge. It is carried by the 1st captain.

The *boring-bit* is also of wire, terminated by a case-hardened gimlet-point, and fitted with a wooden handle; it is used for removing obstructions from the vent.

The *tube-box* is of leather, fitted with a cover and a strap to fasten it round the waist of the 1st captain; the strap has two loops for the priming-wire and boring bit; the tube-box contains the tubes or percussion-primers, if the latter are used.

The *thumb-stall* is of buckskin, with a pad stuffed with hair at the extremity; it is worn on the left thumb by the 1st captain, and is used to stop the vent; in the new percussion-lock, this is superseded by the vent-stopper.

The *sponge* is composed of the *staff* and the *head;* the latter is covered with a sheep-skin dressed with the wool on; army sponges are covered with a fabric made of coarse well-twisted woollen yarn, which is said to be superior to the sheep-skin. The sponges used in the naval service have a *worm* in the extremity, which saves the time necessary to pass a separate worm to remove the remains of the cartridge. Sponge heads are eight inches long, and one inch less in diameter than the calibre of the gun: for chambered guns, the head conforms to the slope and chamber.

The *rammer* is composed of the *staff* and *head;* the

staff is six inches longer than the length of bore; the head is made of any tough wood, in length equal to the diameter of the bore, in diameter seven-eighths of the calibre. The head of the rammer is hollowed to enable it to shove the grummet wad close home, and for chambered guns it is tapered at the extremity, that it may push the reduces home; the *sponge-cover* is a painted bag, which protects it from wet and injury.

The *worm* is composed of two spiral branches pointed and turned in opposite directions, secured by rivets to a staff; it is used to draw the charge.

The *ladle* is a copper *scoop* mounted on a head furnished with a staff; it is used to extract the shot, or to remove loose powder from a torn cylinder: but a single worm or ladle is furnished to each division.

The *passing-box* is a cylinder of leather; its inside diameter is equal to the calibre of the gun; its length sufficient to contain the charge: it is fitted with a cover secured by a laniard, and has the number of the gun painted on the outside; it is used to protect the cartridge from accidental fire during its transit from the magazine to the gun.

The *match* and *staff:* the *staff* is of wood turned, about two and a half feet in length, with a *ferule* and *point* at one extremity; the other end has a mortice six inches in length: the *match* is wrapped around the staff, and the extremity thrust through the mortice, where it is secured by a peg: the percussion-lock has superseded the match.

The *match-tub* is a conical tub, with a cover pierced with several holes; it is filled with water when clearing for action, and contains the match when

not in use: it is marked with the number of the gun. Iron work.

The *swab* is of rope-yarn middled through a *grummet*, and the parts seized together; it is used to extinguish accidental fire.

The *fire-bucket* is of leather, furnished with a handle of rope covered with leather, and a laniard of sufficient length to reach from the hammock-rail to the water: it is used to draw water for extinguishing fire, and when not in use hangs upon a hook between the ports: it is also numbered.

The *battle-lantern* is used on the main and lower decks of ships during night actions; it is, in general, a hexagonal frame of copper glazed, and when not in use is placed in the fire-bucket.

The *handspike* is a lever of oak or hickory, shod at the large end with an iron *shoe*, which prevents the end from splintering; the smaller end is rounded it serves to raise the breech in elevation, or to train the carriage in pointing: one is furnished to each gun.

The *crow* is an iron lever having one end square, and terminated by a *claw*; the other extremity rounded, and terminated by a point: one is furnished to each gun, and it is used for the same purposes as the handspike.

The *chocking quoin* is of wood, hollowed to fit the truck, and furnished with a handle affixed to one of its parallel faces; it is placed before the truck when the gun is in, or in the rear when the gun is out, to prevent the carriage from moving.

The *tompion* is of wood, fitting loosely the bore of the gun, and connected by a laniard to a wad fitting the bore tightly; it closes the muzzle, and prevents the entrance of moisture.

The *muzzle-bag* of painted canvas is placed over the muzzle at sea, and secured by a laniard; it prevents the access of moisture to the charge.

The *gunner's apron* is worn by the quarter-gunner of the division, and contains spare articles required during an engagement.

The *budge-barrel* is a wooden keg, copper hooped, and furnished with a cover of bag-leather, which is *pursed*, or drawn together by the *cord* which passes through holes pierced in the cover; the cord passes through a *cap*, or *hood*, which closes the aperture: it is used when bringing up a quantity of powder from the magazine, as in firing salutes.

The *wads* used are either *junk* or *selvagee*; the former are of rope-yarn beaten in a mould, and wrapped with other yarns, to prevent them from losing their shape: the latter are of yarns made in the shape of a ring: both kinds are used to retain the shot in its place. (Vide Art. 344.)

The *shot* are solid, hollow, grape ,and canister: for description, vide Chap. V.

CHAPTER XV.

PREPARATION OF GUNS, GUN-CARRIAGES, AND MATERIAL FOR SERVICE,—SERVICE OF GUNS.

338. As the armament of a ship is placed on board of her under the immediate inspection of an officer deputed for that purpose by the Ordnance Department, it is to be presumed that it is fit for service, and it only remains for the officers of the ship to equip and preserve it in efficient fighting order. If suitable means are adopted at the outset, this may be accomplished with a very little labor, while to defer it is to increase that labor in a tenfold degree.

A personal examination should be made of the locks, sights, tompions, rammers, and sponges; the first two should be fitted, and the hammer of the lock sprung to ascertain whether it strikes fairly over the vent. The wad-screws upon the sponges should be examined to see if they will act, and the rammer that it is hollowed sufficiently to push home the selvagee wad: the spare equipments should be included in this examination.

339. The gun should be scraped bare, and all blisters removed with a smooth file; the holes, if there are any, being puttied. Apply two thin coats of red lead, well ground in oil, and when they have sufficiently hardened rub it smooth with sand-paper, or coarse canvas; then

Of the guns

give it one coat of black paint with a brush, and when it is sufficiently dry apply another coat with the hand, rubbing it well for half an hour; a daily rubbing with the hand, or a woollen cloth, and occasional application of a little boiled oil, will produce a polish equal in beauty and durability to japan varnish: should the paint be scraped off by accident, rub on a little by hand until no trace of the injury remains.

Neither the gun nor the carriage should be wet; the dust or dirt collecting upon them should be brushed off with a soft shoe-brush.

Of the equipments.

340. The equipment of a carriage requires a breeching, two side tackles, a train tackle, two chocking quoins, elevating screw, or bed and quoin, and a crow and handspike. A certain number of spare articles, trucks, etc., is allowed: it is evident that for small vessels this number should be proportionally greater than for those of a larger class.

These articles are of a regulation size, but it would be well to see if the breeching will reeve (vide note, page 223); and the shells of the blocks might generally be eased with advantage—in most cases one half, and sometimes a greater part of the force is employed in overcoming the friction and binding of the tackles against the shell. The breeching and tackles should be lightly rubbed with a mixture of tar, lampblack, and oil, thinned with spirits of turpentine. The tackles should never be flemished down upon the damp decks, both because it prevents the decks from drying, and that it swells the tackles so that they do not work readily through the sheaves, and they are rotted by the wet: on the score of cleanliness, if for no other reason, this too common practice should be abandoned.

If the carriages are to be kept black, as is usual,

the neatest and far the most durable method is to stain them; this is effected by scraping off all the paint with knives and pieces of glass to leave the wood smooth, and then applying the stain: the cracks and holes are to be filled with black putty, and after the stain has been applied three or four times, give the whole a coat of boiled oil. If they are rubbed occasionally with boiled oil, this will dye them of a permanent black.

The linch-pins, shackle-bolts, and other parts requiring it, should be removed at least twice a week, cleaned from rust, and greased. The pins upon which the sheaves of the blocks traverse should be knocked out occasionally, and the sheaves oiled to reduce the friction occasioned by their rubbing against the shell. The trucks should be removed at least weekly, cleaned, and rubbed with black lead inside or slushed. Finally, every precaution should be taken to preserve every part from rust, and the breeching and tackles from rot or injury.

In lieu of the old method, breechings are at present fitted with thimbles to shackle to the bulwarks; and the gun is either fitted with a shark's mouth, or, in guns of the old pattern, the ring is cut to allow the breeching to be snatched; by this arrangement the operation of shifting a breeching is greatly facilitated.

Shot.

341. It is to be presumed, that the shot do not fall below the established amount of windage, they therefore require no examination on reception; they should however receive a greater degree of attention than is usual, after they are placed on board ship. If a great accumulation of rust should take place, the shot may jam in the gun and cause it to burst; or, should it not be used, the removal of the rust before it is issued for a second cruise takes off a scale of metal, which in-

creases the windage, and consequently the inaccuracy of the fire. The shot-locker is usually under the main hatch, consequently when it rains, or in washing decks, a quantity of water falls on the hatches which cover them, and runs through on the shot below. Frequently the shot are not disturbed during the cruise, and on the return of the ship are found rusted into an almost solid mass. Either before reception on board, or early during the fitting of the ship, each shot should be carefully cleaned and coated with lacker; after being thoroughly dried they may be placed in the locker, which should be covered with grating hatches to permit a free circulation of air; a tarpaulin cover will protect them from wet, and a yearly examination of the shot will afterwards suffice.

Shells. 342. Shells are always furnished boxed up, and a portion fuzed and filled for service.[1] The most approved fuze is composed of a composition driven in a paper case, to be inserted just before firing, in a metal or wooden plug, driven in the fuze-hole and accurately reamed out. The common fuze is a conical plug of beech, or other hard wood, turned on the exterior and bored. They are graduated into inches and tenths, and driven with various compositions. If they are not marked, a few should be burned, to ascertain the rate of burning. Those driven with mealed powder generally burn at the rate of 1 inch in 2.2 seconds. Before inserting the fuze in the fuze-hole, a hole should be bored through the composition with a gimlet, or a fine saw run half through the stock, at the length estimated to be necessary to burn the required time. Col. Paixhans proposes that the fuze shall be of metal, and

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[1] By the latest regulations of the Ordnance Bureau all shells are fuzed, and one-fourth filled.

to screw into the shell, being made of various lengths, the proper one to be selected as required. In the French navy they have introduced a screw-cap over the head of the fuze, fitted with a milled head, to unscrew it after the shell is entered in the gun.[1] Colonel Jure proposed, as a substitute, the leaden patch over the fuze, which we have adopted; the patch is to be removed with an instrument similar to an awl, after the shell is entered within the muzzle of the gun.

The charged shells will, of course, be placed in the shell-room; the remainder may be stowed in the wings, or other dry place. Every shell should be passed through the cylinder gauge before being placed in the shell-room, to ascertain whether it will enter the gun.[2] The uncharged shells should also be examined to ascertain whether they have a *filling hole*, as it is an exceedingly difficult operation, consuming much time, to drive the fuze if the charge is first put in the shell. If the fuzes are driven in paper cases no filling hole is required, as the powder can be poured through the orifice before their insertion.

If the common wooden fuze is supplied, and there is no filling hole, the charge must first be introduced, and the fuze afterwards driven. The fuze being long enough to reach the opposite interior surface, which is necessary to prevent it from being driven in by the force of impulsion, the shell must be held, fuze hole down, while driving the fuze, which is inconvenient. If the shell is damp, it should be thoroughly dried before being filled.

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[1] A shell thus fitted exploded on board the English practice ship Excellent, while unscrewing the cap.

[2] In the last vessel in which the author served it was ascertained, *after the vessel was at sea*, that less than one-third of the shells would enter the guns; other officers have made a complaint of like carelessness in this respect.

Grape and Canister.

343. Grape and canister are furnished in small quantities. They are, however, of very little service on board vessels larger than sloops, their principal use being against boats and for sweeping an exposed beach in protecting a disembarkation of troops. They should be stowed in a dry place; the grape, if quilted, occasionally aired, and painted when necessary. Some care should be taken to avoid bruising the canister, as it is sometimes difficult to enter it in the gun.

Wads.

344. There are three species of wads used in the navy:

1st. *The selvagee cleft wad* has the advantage of lightness, occupies but a small space, less expense of fabrication, increases the accuracy of fire, holds the ball better in its place, and facilitates loading.

2d. The *grummet wad* has all the preceding advantages in a lesser degree.

3d. The hard or *junk wad.* This wad is apt to swell, so that it cannot be entered in the gun, and if forced by blows of the rammer, spreads and jams in the bore, endangering the gun if fired under these circumstances, and causing delay if extracted by the assistance of the wad hook. It increases the recoil, diminishes the accuracy of fire, and, in short, possesses none of the advantages of the selvagee wad. It is more cumbrous, costs more, and is more likely to favor and sustain accidental fire. Stowed in damp places, it heats and decays, and aboard ship it affords a lodgment for insects.

In chambered guns, when the rammer has a reduced section that it may force the reduces close home, the grummet wad cannot be used, unless we have two rammers. In this case, if the cartridge should burst in the gun, or the gun is to remain a long time loaded, the hard wad should be used. It is also used in firing salutes.

345. We have before stated that velocity of recoil is the element which determines the charge of a given gun.[1] Proportioning charges.

This may be restrained within the limits which experiment has found necessary, by giving the gun great proportional weight, by friction properly arranged, or by reducing the charge. The proportional weight must, however, have been decided by considerations previously discussed; and the second method requires too complicated a machinery to authorize the adoption of it for broadside guns. It therefore becomes necessary to reduce the charge to such a quantity as will impress but a safe degree of recoil upon the gun.

The *moment of recoil* is of comparatively slight importance, provided one of its elements, the velocity, does not exceed the limit; for the moment of a long gun, although much greater than that of a carronade, is productive of less injury to the vessel, since its weight checks the recoil, and renders the strain upon the breeching less abrupt.

The relative velocities with which the gun and projectile take up motion will be in the inverse ratio of their masses; consequently, the momenta, or product of

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[1] The necessity of limiting the *velocity* of recoil, or, in other words, the necessity of giving the gun great inertia, cannot be too strongly insisted upon. No increase of weight in the carriage, or arrangement for checking recoil with the aid of friction, can compensate for a want of sufficient weight in the gun. The action of the gun is precisely similar to that of the projectile; and by the laws of impact (Art. 11), the destructive effect of the former upon the carriage, and the strain upon the ship's side, will increase in a greater proportion than the decrease of its weight; for, by the principle of living forces, the destructive effect is as the square of the velocity multiplied into the mass, and not proportional to the simple velocity as it is generally supposed. But, since the weight of the gun has been previously fixed, the charge must be so established as to restrain the *initial* velocity of recoil within such limits as experiment has determined to be necessary.

Proportioning charge.

the mass by the velocity of each will be equal; but as the gases produced by the combustion of the charge have the same weight as the charge itself, it follows that the bottom of the bore is reacted upon by the force necessary to expel the charge itself from the gun, and that even after the ball has left the gun, these gases, on account of the resistance of the air to their free expansion, continue to react upon the gun and increase its recoil.

From these facts, we may conclude that the accurate determination of the moment of initial recoil is a matter of considerable difficulty. For all practical purposes we may, however, assume that it is, relatively to the projectile, in the inverse ratio of their weights.

Experiment has determined that a charge of $\frac{1}{4}$ will impress upon the ball a velocity of 1600 feet per second, and that the recoil of a long gun, with a proportional weight of 200 to 1, is not too great to be injurious. We may, then, assume eight feet per second as the safe limit of initial recoil.

To ascertain the charge for a gun of less proportional weight, we first ascertain the moment of the gun by multiplying its weight by eight, the limit of recoil; dividing the product by the weight of the shot, we obtain the maximum initial velocity of the shot. This being fixed, we proceed to determine the charge. We have before shown, Art. 153, that this may be, for small variations, considered proportional to the square of the velocity; consequently, we have the proportion:

$$V : V' = \sqrt{C} : \sqrt{C'};$$

or, 1600 is to the fixed initial velocity as the square root of one-fourth the weight of the ball is to the square root of the required charge.

Proportioning charges.

The proportionally light guns in service, such as carronades, and the 27 cwt. and 32 cwt. 32-pounders, have a very lively recoil, particularly the last two; for this reason, it has been proposed to abandon the use of solid shot from the 27 cwt., as the recoil of the gun with the service charge of one-eighth and a solid shot is too great for safety on board ship; the hollow shot having an initial velocity greater by about 200 feet gains in velocity what it loses in mass, while the gun is less strained: for distant firing, hollow shot cannot be advantageously substituted, for they have neither accuracy nor penetration.

If the firing is rapid and continued, the gun becomes heated, and the same charge produces a greater useful effect (Art. 134): combats also take place at various distances, and as a greater effect is produced by a shot with just sufficient velocity to penetrate the side, it becomes necessary to reduce the charge. The charges, reduces, and their ratio to the whole quantity furnished are contained in table.

The reduced charges for chambered guns should have a block of wood in the mouth of the cylinder large enough to completely fill the void, both because it facilitates loading, and that it produces a sensible increase of velocity. By the experiments at Gavrés, it was found that the same quantity of powder in one cylinder gave $\frac{1}{20}$ greater velocity to the projectile than when divided in two bags.

Percussion primers.

346. From the time of the introduction of cannon on board ships until within the last twenty years, the match, or port-fire, applied to a train poured in the vent, and upon the surface of the gun, were the principal means employed for communicating fire to the charge. These means were productive of so much danger and inconvenience that many efforts were made to dis-

Percussi primers.

cover a substitute; the burning grains of the priming of the gun were often blown off, igniting the loose powder spilled from the priming-horn, which sometimes communicated fire to the spare cartridge, producing disastrous explosions. In damp weather the guns on the spar deck could only be fired very slowly, if at all, on account of the dampness of the priming. The captain of the gun having obtained the aim, the explosion was involuntarily retarded by the time necessary to give the order for another to apply the match, during which time the aim might be lost.

The adoption of the flint-lock was a step towards improvement in Naval Gunnery, but this amelioration never met with the approval of seamen in general—a race wedded to the observation of precedent, and jealous of the suggestions of unprofessional talent. The flint-lock, although possessed of the advantages of greater safety, and of placing the fire under the control of the captain of the gun, was deficient in certainty in windy weather, and at all times in that instantaneous communication of fire to the charge—a condition so necessary to the accuracy of fire at sea.

Since the discovery of the various fulminating compounds, the percussion primer has assumed various forms; at present that regarded with the greatest favor is composed of a cap of varnished paste-board, containing the fulminating powder. The cap is to be placed on the hammer of the lock, and passed firmly down with the thumb. Some officers advocate the attachment of a wafer to a quill tube, filled with mealed powder, which is to be inserted in the vent: this arrangement neutralizes the most important property of the percussion primer—its rapidity, without increasing in a marked degree its certainty.

The French use a composition of ten parts of ful

minate of mercury, and six of gunpowder; the latter is added to increase the quantity of flame, and the mass of composition. The English use a composition of 5 parts of chlorate of potash, 2 of sulphur, 1 of charcoal, combined with one-third of its weight of fulminate of mercury: this composition makes a very strong and certain powder. The composition used in our own service is not known; either from defects of fabrication, or of material, they have hitherto proved unsatisfactory in service.

Service of guns.[1]

347. Preparatory to loading it is necessary to sponge the gun, whether it has been discharged or not. In the first case to remove the moisture condensed in the bore; and in the second, to remove any fragments of the cylinder which have not been expelled, to extinguish sparks, and to clean the bore of the residuum of combustion. Sponging.

Upon entering the sponge it is a matter of dispute whether the vent should or should not be stopped. If the vent is stopped, the sponge is with great difficulty pushed to the bottom of the bore, and the condensation of the air favors combustion. If it is not closed, a strong current of air is produced through the vent, which may enliven any remaining sparks, or drive fragments into the vent. The advantages and disadvantages are so nicely balanced that we do not greatly err by adopting either method; the army practice is to leave the vent open on entering the sponge, and close it at the instant of withdrawal: the usual

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[1] For further information upon each of the subjects under this head, see the gun exercise.

practice in the navy is to close it from the beginning. I prefer the former method. Under no circumstances whatever should the sponge be wet, as it causes the formation of a paste in the gun, which may retain fire, and inflame the next cartridge. After the sponge reaches the bottom of the bore it should be turned from left to right through an entire revolution, that the worm may seize the fragments of the cartridge remaining in the bore, and then be briskly withdrawn.

Loading with cartridge.

348. The gun having been carefully sponged, the cartridge is to be entered bag end first, and seam down, or on the side; it is then to be pushed to the bottom, which is known by a mark on the staff, or by the captain of the gun feeling it with the priming-wire: if the cartridge is not home, the percussion primer may fail to ignite it.[1] If the gun is to remain a long time loaded, a wad should be put over the cartridge to prevent it from absorbing the moisture condensed upon the surface of the shot.

Shot.

349. The shot with a grummet wad over it is next to be entered, and both driven home together; when the captain of the gun feels by the jar upon the priming-wire that they are home, the rammer is to be withdrawn.

Shell.

350. The shells are placed in a box, fuze down, and when brought to the muzzle of the gun the lid is taken off, and the shell entered; the cap, or gummed cover, is then to be torn off, and the *leaden patch* removed with the instrument provided for that purpose; at the same time pricking up the quick match. The shell is to be entered fuze up, and *pushed* care-

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[1] Lieut. Ward, page 79–80, erroneously asserts that it would also endanger the gun. The case is not similar to that in which a vacant space exists between the powder and the shot.

fully home, observing not to turn the rammer lest it should alter the position of the fuze. In loading, even a grummet wad is unnecessary, and may prevent the fuze from igniting; the *sabot* is sufficient to hold the shell in its place. In the English navy a light grummet is gummed to the shell before it is placed on board ship.

Double shotting.

351. A desire to discharge upon an enemy a great number of missiles has led to a practice of double and even treble shotting guns. The practice at this day finds few advocates, as they have neither sufficient accuracy nor penetration to compensate for the increased strain on the gun and breeching.

A 32-pound shot from a double-shotted gun, with a charge of one-third the weight of a single shot, cannot be expected to penetrate 30 inches into oak at a greater range than 100 yards. At a range of 500 yards the double shot may penetrate to the depth of 18 inches. It is, however, necessary to reduce the charge when we double-shot the gun, for the force developed is greatly increased by the greater inertia of the two projectiles (Art. 164), consequently the penetrating force of double shot is insufficient except at the closest ranges.

Treble shot can never be expedient, as they cannot penetrate 30 inches at the closest ranges.[1]

Double shot may be used with advantage for ricocheting against boats and uncovered troops, whereby the chances of hitting are greatly increased, and their momentum is sufficient at the extreme range to destroy the slight frames of small craft.

In double-shotting it is usual to place a wad between the shot, but the practice does not appear to be

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[1] Simmons,—page 72.

advantageous; for the rear shot may, by compressing the wad, acquire sufficient velocity to break the other, and be wedged back by the fragments, when, if in contact, they would move off as one projectile. Treadwell also says: "The use of junk wads between the shot seems to have very much increased the lodgment."[1]

Grape.

352. The experiments made at Gavrés, from 1830–40, afford us a great deal of information relative to the effects of various methods of loading upon the range, penetration, and spread of grape.

The most important facts elicited by these experiments are the following:

When the *grape* is next the powder, the dispersion, or spread of the grape, acquires a value double that which it has when the ball is in contact with the charge.

Thus a simple change in the position of the ball and grape varies the dispersion in the ratio of 2 to 1.

The dispersion of the grape is not sensibly influenced by the variation of the charge.

A wrought-iron plate between the powder and the grape diminishes the dispersion.

Any body in the gun after the grape increases the dispersion.

When the *grape* is next the cartridge the plate is often broken; if not broken, it is much curved with the convexity towards the powder; the grape leave on it deep prints: as it is forcibly driven forward, the stem is retained by the shot, and they advance togegether; the balls are often broken.

When the *shot* is next the cartridge the plate is less curved, and its concavity is towards the ball: the

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[1] Account of an improved cannon.

prints of the grape are slight, and it is seldom that the plate is broken. In all cases we perceive that the curve of the plate has its concavity towards the ball. Grape.

The velocity of the *ball* is increased by putting it in last, but the velocity of the *grape* is increased by putting the ball in first.

A wrought-iron plate increases the velocity of the grape.

$\frac{7}{11}$ of cast-iron plates were broken in the gun.

The total weight of the stand remaining the same, the *velocities* of the balls composing it experience no sensible variation.

For the same gun, the *dispersion* is proportional to the cube root of the number of balls composing the stand.

The total weight of the stand being the same, the *dispersion* is in the inverse ratio of the diameter of the balls composing it.

The *dispersion* is also in the inverse ratio of the square roots of the length of bore.

For the same gun, the *dispersion* is proportional to the distance, and is about one-tenth the distance.

The initial velocity of grape is about three-fourths that of a ball with the same gun and charge.

By attention to the preceding facts, we may vary the manner of loading so as to produce the required effects.

Grape is of little service except against boats and small vessels, the scantling of which is too thin to resist even the smallest missile.

353. The English understand by the term *point-blanc range*, the distance from the muzzle of the gun, the axis of the bore being horizontal, to the point where the shot discharged with the maximum initial velocity crosses the plane tangent to the trucks of the Ranges.

carriage. By this definition, the point-blanc depends not only upon the calibre and charge of the gun, but also upon the height of the carriage, which varies with the class of vessel and the service for which she is armed.

In the U. S. Navy this definition has been generally adopted, but in all other services, both land and sea, except the English, point-blanc is differently defined.

Point-blanc. Plate I. The point-blanc of a gun is the point where the trajectory intersects the second time the line of sight produced. (Fig. 24.) The point-blanc consequently depends upon the charge and angle of sight alone; the French, in general, place the point-blanc of their batteries in harmony, at about 800 yards; that is, the line of metal ranges of all calibres are equal. The advantages of this arrangement are, that within the limits of penetrating distances the guns may all be pointed the same distance above or below the point to be struck; consequently a seaman familiar with one calibre could without entailing a confusion of ideas be transferred to another gun: since the introduction of tangent-sights this is of no particular advantage. The preceding definition of point-blanc is adopted in this treatise.

The *ranges* of guns depend upon their calibre, charge of powder, and elevation: these, within the limits of penetration, for all classes of guns in service, are given in Table I., taken from the English. It is understood that a table of ranges is being constructed, from actual practice, under the direction of the Ordnance Bureau, which when issued will supersede the one given.

The ranges of all calibres vary more when the guns are fired under small angles of elevation, than when the range approaches its maximum.

Ricochet. **354.** When guns are fired over the sea, the hori-

zontality of its surface frequently causes the projectile to rise after striking the water, and describe numerous trajectories of limited height; that these ricochets may take place, it is necessary that the angle of fall should not exceed 5° to $8\frac{1}{2}$°—the greater angle corresponding to the lowest velocity. Ricochet.

The projectiles of heavy guns lose but little of their velocity after ricocheting under angles of 4° or 5° on the water;[1] the ball of a 24-pounder, for example, preserving sufficient velocity after a ricochet to penetrate the side of a ship of the line at 600 or 700 yards.[2] This gives a battery placed on an eminence the advantage of a direct and also ricochet fire upon shipping, provided they cannot approach nearer to it than a distance $x = \frac{y}{0.15}$, corresponding to the greatest angle of fall $8\frac{1}{2}$°; y being the height of the gun above the surface of the sea. As ricochet is particularly advantageous from shipping, a sea-coast battery should be placed at such an elevation that it can only be reached by direct fire; the greatest height of the curve which a ball describes after ricocheting upon water, being from 15 to 20 feet.

Experiment shows that the nearer a gun is placed to the water the longer will be the range, and the more numerous the ricochets; there might, therefore, be an advantage in heeling the ship by running in the opposite guns; there is also an advantage in firing en ricochet with the wave rather than against it: the vessel to windward is consequently enabled by position to use it most advantageously.

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[1] Captain Stevens, of the English Navy, in a pamphlet on "Pointing Guns at Sea," evidently translates this passage incorrectly; it is not the angle of elevation of the gun, but the angle of incidence on the water that is meant.

[2] Vide Memoir on Sea-coast Batteries.

Ricochet.

A 32-pounder on the main deck of a ship will furnish ricochet, if fired with the full charge, up to a range of 2000 yards; but if mere range be the object, it can be increased by firing the gun at an elevation not greater than 2°. The full charges alone should be used, as the projectile is greatly retarded by numerous grazes, and at the end of its flight rolls upon the water incapable of producing injury.

When the sea is smooth, ricochet doubles the chances of hitting a target at 600 to 700 yards distance; it follows that we should point low, rather than high, thereby preserving the chances of a ricochet. A slight ripple diagonally across the line of fire frequently produces great deflections from the line of aim.

Deviations.

355. The chances of hitting any object diminishing with its extent, and also with the diminution of the length of bore, charge of powder, diameter and density of the projectile, and elevation of the gun, it follows that it will be an unnecessary and wasteful expenditure of ammunition to open a fire upon any object, the extent of which does not surpass the mean deviations of several successive rounds. In naval gunnery, we have in general a target of considerable extent, but of limited height; and it happens that it is in this last direction that the greatest number of causes combine to prevent us from attaining the object: for in addition to the general causes of deviation, the rapidity of the rolling of the ship changes the elevation of the gun between the instants of exploding the primer and the parting of the shot.

By the experiments at Gavrés, it appeared that when the pointer of the gun was intelligent and well drilled, the accuracy of shot fired from a floating platform was equal to that fired by the same man from a fixed battery, but that the mobility of the target ren-

dered the aim much more difficult; consequently the rising and falling of the enemy is of more consequence than the motion of our own vessel. For these reasons, we should endeavor to deliver our fire when the enemy is at a stand on top of a swell, and also pay great attention to the first few rounds, to correct a faulty estimation of the distance. Deviations.

CHAPTER XVI.

INSTRUCTION AND GENERAL DETAILS.

It is pre-supposed that the battery is provided with tangent sights, percussion locks, chocking quoins, and grummet wads.

It is evident that the following exercise has a tendency to increase the rapidity with which the gun can be served; but is it likely to produce a dangerous precipitation? In the service of the gun there are two distinct parts,—loading, and the pointing.

One of these, the *pointing*, cannot be executed with too much care and method. The captain of the gun should retain all his calmness—all his attention. The other part, the *loading*, cannot be performed too quickly. We should endeavor to gain all we can by promptitude, provided that we risk neither the safety of the crew nor the gun. It is evident that, with equal accuracy and the same precautions, the advantage is with him who loads most quickly; and if it should happen that aim is no longer but an accessory by reason of the diminution of distance, then the success is evidently with him who is trained to load soonest.

Pointing, then, should be slow, careful, and methodical; loading should be executed as promptly as possible. It was for this last reason that the employment of the simultaneous charge was suggested. Cartridges of the ordinary shape only require that the powder be closely shaken, and the neck cut

off close to the tie, or stitched back in the form of a rosette, and no difficulty will be experienced in loading.

With chambered guns selvagee wads cannot be used, unless we employ two rammers, or the reduced cartridges have (as they should always have) a *sabot* attached, which will permit us to use *full* rammers.

In the formation of the exercise, the author has endeavored to combine all the advantages of the French and English systems.[1] It has at least one merit, that of conciseness;[2] and if it is defective in some particulars, he hopes that officers of greater experience will recollect, that during the ten years of his service there has been no established exercise, and that in most ships not only each officer but each captain of a gun uses a different set of orders.

In the explanation of the duties following the commands, the detail is made as concise as possible; but the notes will contain those facts and the rules of pointing which should form the basis of instruction at division exercise.

Stationing the Crew.

The crew of a ship should be quartered by the watch-bill in such a manner as to bring, so far as practicable, the petty officers and every individual likely to be called upon during action in that part of the ship where the secondary duties are to be performed.[3]

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[1] Vide Exercises des Bouches à feu en usage dans la Marine.—Manœuvres du canon.—Canonnage à bord.—Instructions for the exercise and service of great guns on board her Majesty's ships.

[2] When the author first entered the service, he asked the officer of his division to give him a list of the orders to be used in exercise. The list given contained 27 distinct orders. Another officer on board the same ship gave but three: fire—load—run out.

[3] In the opinion of the author, the Quarter and Watch-Bills in the appendix to Ward's Gunnery are the best yet published. He does not, however, approve of the recommendation on page 32, to station the whole crew in that part of the ship where they are watched.

The crew of each gun and its opposite, when an even number, are to consist of equal numbers of men from both watches; when an odd number of men are stationed as the crews of the guns, the odd man should be alternately of the starboard and port watch, and they should be selected as much as possible from various parts of the ship, so that if a heavy loss of men should be suffered at particular guns, it shall not be more severely felt at any one station than at another.

The gun and its opposite should bear the same number, and be numbered from forward, beginning with No. 1 on each deck.

The first captains, and half the crew of the guns (the men designated by the odd numbers), are to belong to the starboard watch; the second captains and the remainder to the port watch.

In stationing the men at the guns, the force usually assigned is one man for every 500 lbs. of metal in a gun mounted on a truck carriage, or 450 if on a slide carriage, with a powder boy to each gun.

The essential stations to be filled are, in the order of their importance: captains, 1st and 2d; loaders, 1st and 2d; spongers, 1st and 2d; crowmen, 1st and 2d; shotmen, 1st and 2d port-tackle, side-tackle, and train-tackle men.[1]

Captains of guns should be selected as good marksmen, men of character and activity, experienced generally as seamen, capable of instructing the guns' crews in the minutiæ of the exercise, and possessing the necessary degree of information in respect to the loading of guns, ranges of shot, &c.

Loaders should be stout men, capable of handling large shot with ease; also men of coolness, who will not be likely to commit an error in loading, which might disable a gun during the remainder of an action.

Spongers should be long-armed men, who can manage

[1] Vide Appendix, Ward's Gunnery, page 2.

their sponges without getting into the ports; also be men of activity and coolness.

Crow-men should be among the heaviest men at the gun, that their weight may be effectual when elevating or depressing.

Powder-boys ought to be strong enough to carry with security and ease two full charges for the guns they attend.

The men appointed to work the gun are to be distinguished by numbers: the service of any gun, whatever its size, requiring but six principal stations to be filled, the first six will be called the standing numbers; they are to be held responsible for the performance of the various duties, and the additional men required for running out and training are to be considered merely as auxiliaries; but they are to be equally instructed in the various duties, and numbered in continuation of the first six. To the auxiliaries will be assigned duties in the following order, depending upon their number: crow-men, shot-men, firemen, port and traintackle-men, and sidetackle-men.

The crow-men are the fourth[1] from the ship's side, with eleven men and upwards; the third, with ten, nine, or eight men; and the second, with six men.

Assembling at Quarters.

This is done at the usual call to quarters. In the English service, in addition to the usual beat to quarters, one ruffle is beaten to signify that the call is for exercise, two ruffles for muster and inspection. Lieutenant Ward recommends a ruffle and a beat for inspection, a beat alone for exercise and action: the ruffles are to precede the beat.

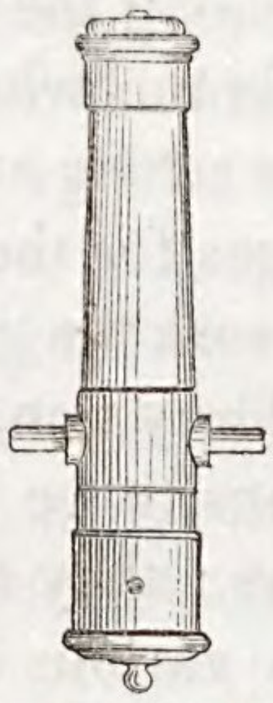
The men will then take their stations, and assume the du-

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[1] If at a greater distance they could not assume their positions in elevating or training, without displacing others of the crew.

ties in the following order. The crews of the odd numbered guns on the starboard side, even numbers port side :

Duties.	No.		No.	Duties.
1st loader, . . .	3		5	1st sponger.
2d loader, ...	4		6	2d sponger.
1st shot and wad, . .	7		8	2d shot and wad.
1st crowman, . . .	9		10	2d crowman.
1st fireman and pumper,	19		12	2d fireman and pumper.
1st port tackle-man, .	13		14	2d port tackle-man.
1st captain, . . .	1		2	2d captain.



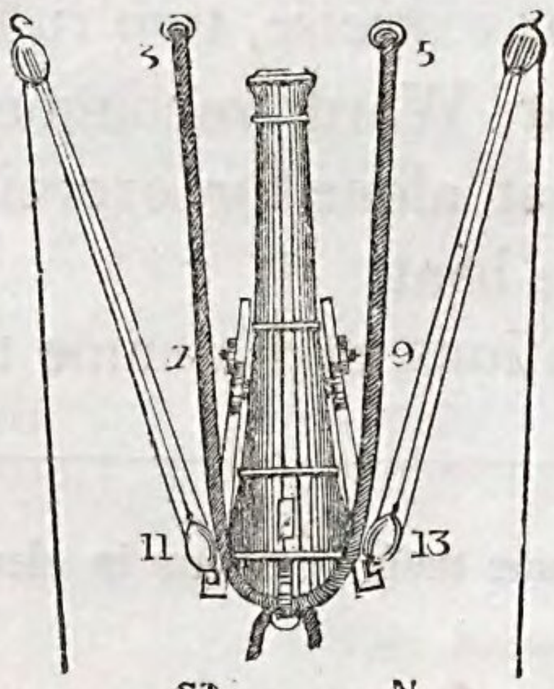
15 powder boy.

The crew, with the exception of the first and second captains and powder-boy, are to stand with their faces turned obliquely towards the gun and the port, this position being best adapted to secure attention. If the call is for inspection only, they will face amidships.

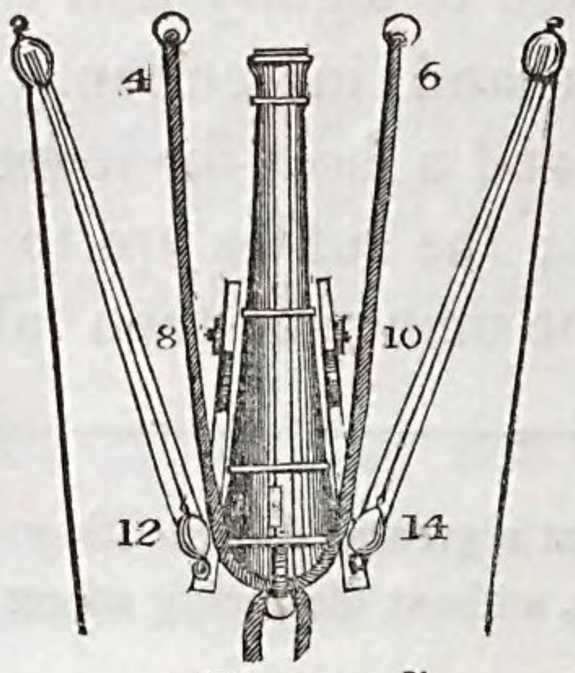
The two men whose numbers place them farthest from the ship's side, are to be termed right and left Rear-men.

Clearing for Exercise or Action.

At the order, *cast loose the battery*, the crew of each gun divides; the first part of each odd numbered gun casts loose its own gun, the second part casts loose the gun next abaft; the first part of each even numbered gun casts loose its own gun, the second part the gun next forward, taking positions at the gun in the following order :



1ST Capt. N



2ND Capt. N

Powder-boy.

The *Captains* equip themselves with tube-boxes, thumb-stalls, and place the priming-wires in their belts; clear away and middle the breechings, and level the guns. They also see the boring-bit in place, and provide themselves with a spare priming-wire and lock-string, and oversee the crew generally.

Nos. 3 and 4, assisted by 7 and 8, cast loose, bear out the ports, take off the muzzle-bags, out tompions, fill shot-racks, and wad-nets, and place them to the left and in the rear of the guns, and hook and mouse the side-tackles to the fighting-bolts; also provide a wet swab.

Nos. 5 and 6, assisted by 9 and 10, cast loose, place the rammers and sponges on deck, heads amidships, take off the sponge covers, hook the side-tackles, heave up the breech that the captain may level the gun, and place the hand-spikes on deck, handles amidships. They also see the lantern and fire-buckets in place, and fill the match-tubs; if at night, light the lanterns.

The right Rear-man will assist in casting loose, hook and mouse the train-tackle, place the match in the tub, and, if in a ship of the line, lead out and attend the port-tackle.

The left Rear-man will assist in casting loose, provide a spare breeching, and assist the Quarter-gunner in placing the side arms and pistols in the racks. He will take the place of the powder-boy, should the latter be disabled.

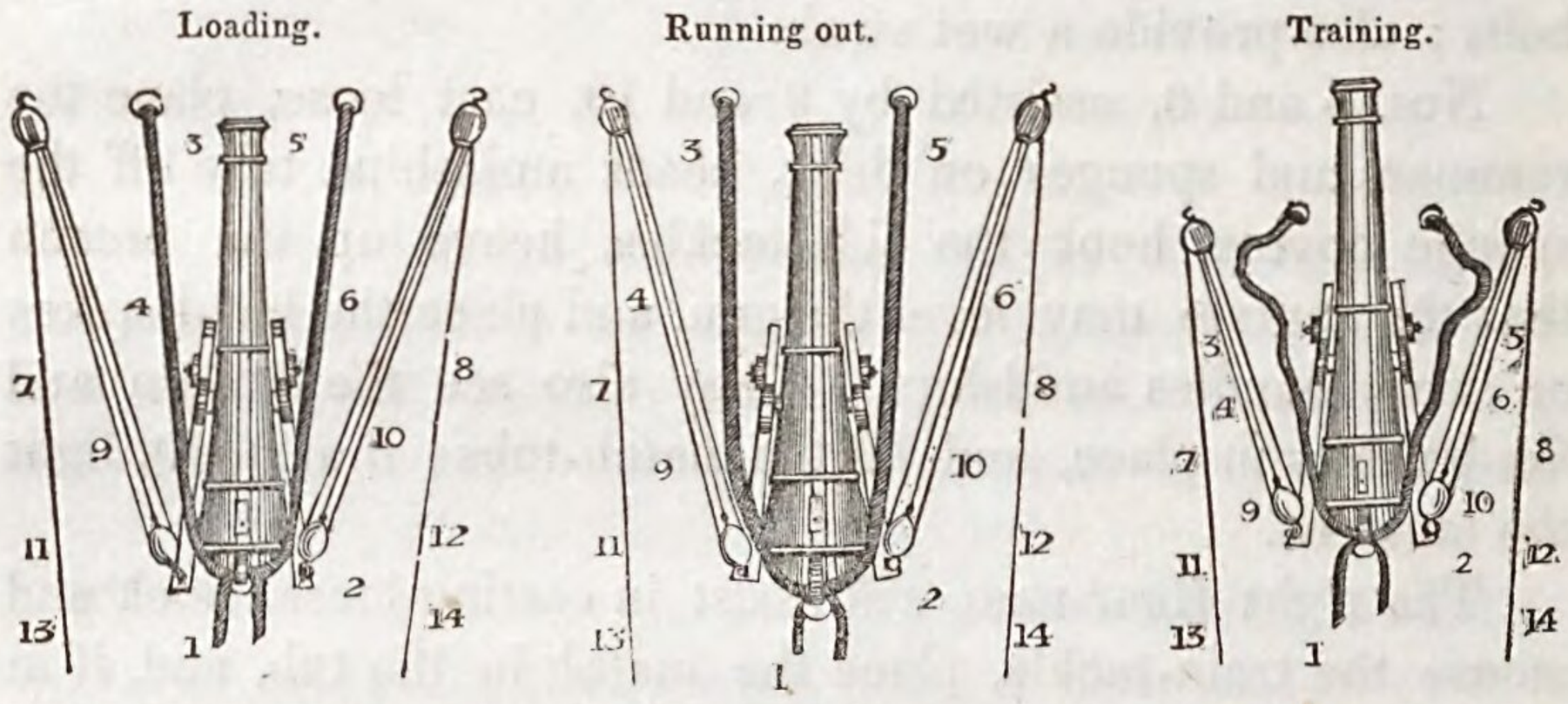
The powder-boy will obtain from the Quarter-gunner the tube-boxes, thumb-stalls, matches, spare lock-string, and priming-wire, and deliver them to the persons appointed to receive them; he will then repair to the hatch, and having obtained a full passing-box, will return to his station.

The Quarter-gunner will deliver the equipments, light a match and place it in a central position, and will then, assisted by the left Rear-man, procure the arms of the division, and place them in the racks.

If called to quarters at night, the half-ports will not be lowered without an order from the quarter-deck: on the hammocks being piped up, the Rear-men of the spar-deck guns will stow them.

The guns being cast loose, implements provided, crew mustered and reported, the order is given to

Man the starboard or port battery. At this order the even or odd numbers shift over, having previously seen the luffs choked, chocking-quoins placed in the rear of the outer trucks, and the implements secure about the gun. The guns are supposed to be loaded. During exercise, or action, the crew will take up positions as in the annexed diagrams :



The officers of division will commence the exercise by giving the

1st Order—*Prick and prime.* The Captain puts the hammer at full cock, removes the vent-stopper, and, entering the priming-wire with his right hand, sees that the vent is clear, and assures himself that the cartridge has not started ; takes a percussion primer from the box with his right hand, closing it with his left immediately, and, placing the primer on the hammer, presses it forcibly down to the head.

2d Order—*Aim.* The Captain elevates the tangent-scale to the range indicated by the officer of division, then places his left hand on the breech of the gun, his right on the handle of the quoin : the crow and handspike men place their handspikes on the steps of the carriage, and raise or lower the breech as directed by the Captain. The Captain steps back

the length of the lock-string,[1] the remainder of the crew man the side-tackles, and, assisted by the handspikes, train at the order, "*muzzle to the right,*" "*muzzle to the left.*"[2] When, by the train and the rolling of the ship, the object comes on with the tangent, he gives the

3d Order—*Drop tackles; fire.* The tackle-falls are immediately dropped clear of the recoil, the handspikes laid upon deck, handles amidships, all but Nos. 5, 6, and 3 spring to the train-tackle to retain the gun in to a taut breeching; the Captain pulls strongly upon the lock-string, at the same time throwing himself back clear of the recoil. Nos. 3 and 5 place the chocking-quoins, and quickly assume their positions at the muzzle. If the ship is rolling heavily, the second crow chokes the luff of the train-tackle. No. 6 passes the sponge to No. 5. If necessary, the gun is levelled.

4th Order—*Stop vent, and sponge.* As soon as the gun is secure, the Captain half cocks, stops vent, and primes. No. 5 receives and enters the sponge, and, assisted by No. 3, pushes it to the bottom of the bore, giving it a few turns to seize any remains of the cartridge, and briskly withdraws it, knocking it against the muzzle, to remove any burning fragments of the cartridge which may adhere to it, then returns it to No. 6, who has placed the staff of the rammer beneath the piece projecting out of the port. The Captain sees the vent clear, and again closes it.

5th Order—*Load.* No. 3 makes a half turn to the left, and receives a cartridge from the powder-boy, which he places in the gun the length of his arm, then the ball and wad successively, which are given him by the shotmen. When the charge is entered, No. 5 enters the rammer, and, assisted by No. 3, steadily shoves it to the bottom of the bore. When, by the mark on the staff, he sees that the charge is home, he signifies the fact to the Captain, by slapping the muzzle, or raising

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[1] The length is regulated by the recoil of the gun.

[2] The terms "*forward*" and "*aft*" should be discontinued, not being applicable to bow or stern guns.

his left hand. The Captain uncovers the vent, and, entering the priming-wire, orders "*ram home.*" No. 5 gives two blows with the rammer, which is then withdrawn at a signal from the Captain, who, feeling the cartridge, waits until the rammer is withdrawn ; then pricks cartridge. The right Rear-man prepares to overhaul the train-tackle ; and the remainder of the crew, Nos. 3 and 5 excepted, man the side-tackles.

6th Order—*Run out.* The Captain takes the handspike from the right, and directs the gun to the centre of the port.[1] Nos. 3 and 5 remove the chocking-quoins, and place them against the side, sustaining the breeching, that it may not jam ; the Captain raises his right hand as a signal, and the crew, giving a strong pull together, run out the gun at a single jerk. The Captain lays down his handspike, and advances to the breech of the gun ; the remainder of the crew, except the crowmen, who take up their crows and handspikes, retain their hold of the tackles.

If the exercise is to be continued, we return to the second order.

Order—*Secure the gun.* The Captain sees the gun level and square in the middle of the port, and, placing the hammer of the lock at rest, covers the vent with the apron, which is handed him by the right Rear-man. He also fraps in the breeching beneath the breech of the gun, breaking down the slack between the cheeks of the carriage and the bed. No. 5 hauls up the half port, No. 3 puts in the tompion, and they then unhook the side-tackles from the fighting-bolts, hooking them to their proper bolts, bowsing them taut, and taking two half-hitches over the tail of the cheeks flemish the end along the tackle. They also hook the blocks of the train-tackle to straps in the side-tackle bolts. The Captain sees all parts of the train-tackle fair beneath the cascable and hauled taut, and all the implements secured in their places. The Second Captain superintends under the direction of the First

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[1] He also, as far as possible, gives the gun the proper direction towards the object, to obviate the necessity of subsequent training.

Captain. No. 6 covers the sponge, and returns it and the rammer to their place. The spare shot, wads, powder, and equipments are to be returned to the lockers, magazine, and store-room by those appointed to provide them, and all the deficiencies in the implements or equipments made good.

During an action it is frequently required to change the side engaged; when this becomes necessary, we

Order—*Attention—cease firing—man the opposite side.* At this order the guns, if not loaded, will be loaded and run out; the luffs choked, chocking-quoins placed in the rear of the outer trucks, and the implements secured. The men will then briskly, but without confusion, hasten to the opposite side, and assume their places at the gun; the 1st Captain will equip himself with the priming-wire and boring-bit, uncover the vent, and see that it is clear, and place the lock at half-cock: he will also see that the implements are in place.

It is also necessary to make some provision for the case of being attacked on both sides at the same time; to meet this exigency, we

Order—*Attention—man both sides.* At this order the crews of all the odd numbered guns stand fast at, or repair to the starboard side, the even numbered guns shifting over to, or remaining at the port side; the crew which shifts over loads and runs out the gun before leaving it; the crew separates as in clearing for action; the captains, spongers, and loaders, remaining constantly at the guns, and the remainder of the crew assist to run out, and train alternately each gun.

NOTES TO THE GUN-EXERCISE.

Cast loose the battery.

As a ship is rarely without motion, it is proper not only to choke the luffs, but also to place the chocking-quoins behind the trucks to avoid accidents; the weather train-tackle may be rounded up to the train-bolt, that it may not encumber the deck, as the chocking-quoins will sufficiently steady the guns against the weather rolls when in for loading.

Prick and prime.

Pricking the cartridge is by no means necessary, as the primers, if good, will always inflame the powder; indeed, the inflammation will be more speedy if the flame experiences some resistance. In priming, it is necessary that the cap, or primer, be forcibly pressed upon the head of the hammer, or it will be crushed without exploding; if the caps fit too closely, they should be split with a sharp knife to allow them to expand.

Aim.

The elevation will be given by the officer of division, or in rapid firing at the discretion of the Captain, depending on the distance and charge.

If the aim is to be very oblique, the aim in direction is first to be taken, then the elevation is to be given.

Rules for pointing.—The details of the exercise show in a general manner the method of pointing in the various cases which occur in an action. We have the following species of aim:

Point-blanc.—The line of sight parallel to the horizontal plane.

Direct.—The gun square in the port, but elevated or depressed according to the distance.

Oblique.—When to bring the object on with the sights, it becomes necessary to throw the breech forward or aft.

Ricochet.—When the aim in direction only is taken, the axis of the gun being horizontal, or at an elevation not greater than 2°; the object being to reach the mark by a succession of bounds.

When the ship is rolling heavily, the gun is to be laid parallel to the deck, and fired when the object comes on with the sights. And, in general, preference is to be given to the aim when the ship rolls towards the object, to insure hulling the enemy, as well as to moderate the recoil, and preserve the chance of a ricochet.

Drop tackles—fire.

The Captain should never fire until the aim is good, tackles are dropped, and the people clear of the recoil. To fire at random is to waste ammunition, heat the gun, fatigue the crew, make a smoke, and lose time uselessly: he should therefore never be hurried.

To explode the percussion-primer a steady pull is necessary; a jerk will not answer: should the lock, or primers, fail *repeatedly*, it will be necesssary to resort to tubes and the match; prime over the tube, and lead a train clear of the vent, slightly bruising the grains with the flask: in applying the match, be careful not to put it over the vent. If there should be a miss-fire,

the Captain should not approach the gun in the line of recoil, but should stand upon the left of the gun, and introduce the priming-wire to see if the vent is clear before he reprimes.

As it will be impossible to take in the slack of the train-tackle fall as fast as the gun comes in, the man stationed to it (the right Rear-man) should seize all parts, and keep a strain on it, that the block may not be split by the carriage running over it; Nos. 3 and 5 should have the chocking-quoins in their hands ready to prevent the reaction from returning the carriage to the port. That the quoins may be easily removed, they should not be placed square under the trucks. In firing with heavy charges, or when otherwise desirable to reduce the recoil, the rear trucks should be taken off.

Stop vent—sponge.

Most of the accidents which happen are occasioned by not stopping the vent; that it may not be neglected, the order is given to stop vent from the beginning. In sponging, the screw is often injured by being struck against the bottom of the bore; this should be guarded against: care should be taken not to wet the sponge, as it would be apt to cause the formation of a paste in the gun, which would retain fire, and inflame the next cartridge.

If the vent is not clear, the Captain is to acquaint the officer of division, and is by no means to reload until after the obstruction has been removed. The boring-bits being of steel easily snap, and are to be used with caution.

Load.

In delivering the cartridge, the passing-box is to be kept open as short a time as possible, that no fire may find entrance. If a cartridge should burst in the box, it should be returned to the magazine; but if it bursts in the gun, a hard wad should be placed over it, and the whole carefully rammed home. To facilitate simultaneous loading, the neck of the cartridge should be left about two inches long, and be stitched back, that it may not jam the shot.

Two shot should never be put in a gun without an express order. In loading with grape, it should always be put in after the ball. The wad should always be put in last, and whatever may be the number of projectiles there should be but one wad. A wad is not put over the cartridge, because it increases the recoil, and takes longer to load.

If the ball will not enter the gun, it is laid aside to be cleaned of its rust. If it jams in the bore, the charge should be drowned, and a few ounces of powder introduced by the vent to blow it out. The staves of the rammer and sponge should always be marked, that there may be no doubt as to whether the charge is home, or that the bore has been well sponged.

Nothing is gained by hard ramming the charge ; it is only necessary to feel by the jar that it is *home*. The priming-wire should not be entered until the charge has been forced home, as guns are often effectually spiked by bending the priming-wire.

Run out.

In a heavy sea, or should the ship have much heel, the right Rear-man when the lee guns are worked, should reeve the end of the train-tackle through the tackle-bolt in the deck, and ease the gun out, to avoid shocks which strain the vessel very much. The Captain should see the gun rnn out square, and in the middle of the port, unless the aim should be continually oblique, when it may be necessary to run out to one side of the port to obtain the necessary train.

EXERCISE OF CHAMBERED SHELL-GUNS.

(*The first four orders as in long-gun exercise.*)

5th Order. *Load with cartridge.*—No. 3 makes a half turn to the left, and receives the cartridge from the powder-boy, which he places in the gun the length of his arm ; No. 5, assisted by No. 3, then steadily shoves it to the bottom of the bore ; when home, No. 5 signifies it to the Captain by slapping the muzzle, or raising his left hand ; the Captain uncovers the vent, and entering the priming-wire orders, *Ram home*, No. 5 gives two blows with the rammer to insure the cartridge being sent home ; the Captain, feeling the cartridge, gives the signal to withdraw the rammer, which being done, he pricks cartridge.

6th Order. *Load with shell.*—The shell being brought to the muzzle of the gun by No. 7, No. 3 raises it from its box, and enters it in the gun sabot first, fuze up, before removing the fuze-cap ; as soon as the cap is removed, No. 5 covers the fuze with the head of the rammer, and gently pushes it to the bottom of the bore ; the captain then orders *Ram home*, at which two gentle taps are given with the rammer to enable the Captain to ascertain if the shell is in contact with the pow

der; if home, the rammer is withdrawn at the given signal (as in long-gun exercise).

7th Order. *Run out* (as in long-gun exercise).

NOTES TO SHELL-GUN EXERCISE.

Aim.

If the gun has an elevating screw, the Captain, placing his left hand on the breech of the gun, seizes one of the branches with his right hand, and assisted by the right Rear-man, elevates or depresses as required; if the required change of elevation is great, the breech should be raised by the handspikes, which will facilitate the movement.

Load with shell.

If by any accident the fuze should take fire before it is entered in the gun, there is time to throw it overboard before the shell would burst. If it should be ignited in the gun, the gun should be run out, and the crew retire to a safe distance. If the shell will not enter the gun (a not uncommon fault), it should be returned to the shell-room. Two hollow shot or shells are never to be entered in the gun, as one of them is always, and generally both, broken in the gun.

MAGAZINE EXERCISE.

As the success of a ship in action depends in a great measure upon the order and regularity with which the guns are supplied with powder, the efficiency of the powder division becomes a matter of the greatest importance, consequently all persons stationed to supply powder to the guns should be frequently exercised, to insure this duty being performed with order and promptitude.

All vessels with two decks are fitted with two magazines, which are placed below the water-line in the extremities of

the vessel. The berth-deck hatches are covered with gratings and tarpaulings fitted with scuttles; up one of the scuttles, the full boxes are passed by hand, and the empty boxes are thrown into a canvas shute affixed to the other. Each box as it comes down is shaken over a tub of water placed near the hatch, the bottom wiped on a wet swab to remove any unextinguished fragments, and it is then passed through the screens to the magazine scuttle; the passing-box is never to be taken into the magazine, but the cartridge is to be handed out into the passage, and put in by the Quarter-gunner.

The divisions on the main-deck are usually supplied from the main-hatch, the forecastle division from the fore-hatch, the powder-boys coming down on the gun-deck; the quarter-deck division from the after-hatch. The powder-boys should be trained to fall into line on arriving at the supplying scuttle, in order that the guns may be fairly and equally supplied. Should the expenditure of ammunition be from any cause more rapid on one part of the deck than another, the officers of division will direct the powder-boys of the unengaged guns to carry their supply where most needed.

The officer in charge of the powder division should prevent any accumulation of full boxes at the supplying scuttles, or within the screens and passages.

In exercise, small wads covered with cotton cloth, or canvas, and painted of different colors to represent the charges and reduces, should be passed up, and by this means it will be readily ascertained if any part of the deck is not properly supplied.

The passing-boxes are usually numbered, but this method causes the boys to assemble in a crowd at the hatch, and some confusion to ensue in the endeavor of each to ascertain the number of the box when passed up; a better method is to cause the boys to fall into line, and have the boxes for each deck painted of a different color. Lieut. Ward recommends

that all spar-deck boxes should be *black*, lower deck *white*, main-deck *black and white*, shell-guns *red*.

By the latest regulations of the Ordnance Bureau, four-fifths of the powder is to be filled in cylinders, one-fifth to be kept in bags of 25 lbs. each; the whole to be stowed in copper tanks arranged upon racks in the magazine.

Of the filled cylinders, when three charges are allowed, one-tenth shall be for distant firing, six-tenths for ordinary firing, and three-tenths for close firing; for 10-inch guns, three-tenths for close firing, and nine-tenths for ordinary firing, when no charge is allowed for close firing.

SUPPLYING SHOT AND SHELLS.

This duty also devolves upon the powder division, but in no ship in which the author has served has he seen any efficient means adopted to procure an adequate supply during action; it is usual to station men at the main-hatch to pass them through the scuttles by hand, but if the shot are even as heavy as the 32, this is a very uncertain method; a tackle, and a couple of stout boxes, iron strapped, large enough to contain half a dozen shot, should be provided; the tackle to be hooked to a strap around a spare spar, or capstan bar, across the spar-deck hatch, and men stationed to whip the shot up: a portion of the grating to be removed when required.

The regulations of the Ordnance Bureau require that one fourth of the number of shells sent on board shall be filled, and the remainder fused and ready for filling. The boxes containing the filled shells are marked with a red cross. A single whip, with a hook at one end, to be taken through the beckets and hooked to its own part, should be provided for raising shells from the shell-room. No accumulation of shells in the batteries should be allowed, for if struck by a shot they may explode, and cause great damage.

SECURING THE GUNS.

The mode of securing the guns indicated in the exercise is that used in port, or in fine weather at sea; but in gales of wind it is necessary to secure them with more care.

The operation of *housing the battery* is frequently resorted to, to take the strain off the ship's side when she is rolling heavily; but it does not, as is generally assumed, moderate the violence of the motion, for it is a well known principle in the stowage of ships, that the rolling is rendered less violent by placing the weights at the greatest possible distance from the plane of the keel, as well as at the greatest height consistent with stability.[1]

To house a gun, run it in, and let the breech down upon the rear axletree; the muzzle rests against the ship's side above the port (placing a mat to prevent chafe), and is to be lashed to the housing-bolt; the side-tackles are to be set well taut, racked, and the ends expended; the train-tackle is to be hooked to the housing-bolt, the single block to a strap over the nob of the cascable set well taut; the parts of the breeching are to be frapped together under the breast of the carriage, and the chocking-quoins placed in the rear of the outer trucks. The lower-deck guns are kept in to a taut breeching, and the *housing chocks*, placed in front of the outer trucks, kept in their place by bolts.

They are sometimes secured by setting taut a stout hawser, or the stream cable, at the bow and stern, seizing it to the cascable ring, and frapping it into the fighting bolts. The strain may be taken off the ship's side by setting taut the train-tackle, and placing the chocking-quoins before the outer trucks.

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[1] Vide Tredgold, page 112.

SHIFTING CARRIAGES.

It is occasionally necessary to remove a gun from a disabled carriage to another; the manœuvre cannot, however, be necessary during an action; there is a housing-bolt over the port, and there should be a dismounting-bolt over the breech.

The gun should be run in, and the breech let down; the muzzle lashed to the housing-bolts, and a runner rove through a single block secured to the nob of the cascable; hook the train-tackle to the runner, unshackle the breeching, throw back the cap squares, and raise the gun clear of the carriage with handspikes and the runner: run under the new carriage, and lower the gun upon it. If the gun is on the spar-deck, it may be lifted by the pendent tackles.

If no other means can be used, the gun may be laid on skids vent down, and the carriage capsized upon it; clamp the cap squares, lash the breech to the rear axletree, and parbuckle the carriage over, easing it down with counter parbuckles.

SHIFTING FROM PORT TO PORT.

Nos. 3 and 5 unshackle the breechings, and hook the side-tackle to the transporting bolts; the right Rear-man hooks the train-tackle to the bolt forward or abaft, and the gun is run in until the train-tackle is two blocks; it is then cut in the proper direction with the handspike.

SHIFTING BREECHINGS.

In shifting breechings, 3 and 5 unshackle from the ship's

side, 4 and 6 from the carriage, 1 at the breech; right and left Rear-man bring up and remove the breeching.

SHIFTING TRUCKS.

If a rear truck, Crow-men place their handspikes under the rear axletree, and lift the gun; right and left Rear-men shift the truck. If an outer truck, Crow-men on *opposite* side lift the rear axletree, Rear-man takes off after truck, and stands on the arm of the axletree: the Crow-man on the *same* side lifts the outer axletree, and the Sponger, or Loader, as the case may be, shifts the truck.

TABLE I.

Showing the Nature, Weight, Length, Diameter of Bore, Charge of Powder, and Range, single-shotted, of various descriptions of Iron Ordnance.

Elevated by quadrant. (English practice.)

	Nature.	Weight.	Length.	Diameter of bore.	Charge.	Height above plane.	Range in yards.						Nature of Shot.	
		Cwt.	Ft.In.	Inches.	lbs. oz.	Ft.In	0—¼°	1°	2°	3°	4°	5°	Lbs.	
Long Guns.	32-prs.	63	9 7	6. 41	10 11	8 0	420	820	1170	1480	1730	1950		Solid Shot.
		56	9 6	6. 41										
		48	8 0	6. 41	8	"	360	730	1050	1320	1540	1740		
		40	7 6	6. 35	6	"	380	720	1020	1280	1500	1700		
		32	6 6	6. 3	5	"	360	700	980	1230	1450	1640		
		25	6 0	6. 3	4	"	250	520	760	1010	1260	1500		
	24	50	9 6	5.823	8	"	400	800	1150	1440	1670	1850		
		48	9 0	5.823	8									
		40	7 6	5.823	8	"	380	780	1120	1400	1620	1800		
		33	6 6	5.823	6	"	280	560	830	1100	1350	1560		
	18	42	9 0	5.292	6	"	400	770	1100	1400	1640	1780		
		38	8 0	5.292	6	"	380	760	1100	1370	1560	1730		
Crraonades.	68	36	5 4	8. 05	5 10	8 0	300	580	840	1060	1240	1420		
	42	22	4 6	6. 84	8 8	"	270	550	800	1000	180	1350		
	32	17	4 0	6. 25	2 10	"	260	520	730	920	100	1260		
	24	13	3 9	5. 68	2 0	"	250	460	670	840	1000	1150		
	8 in.	60	8 0	8. 05	9 0	"	360	660	950	1200	1430	1620	68	
		50	6 8	8. 05	9 0	"	320	600	870	1100	1300	1481	68	
Hollow Shot Guns.	12 in.	90	8 4	12.	12	8 0	280	570	800	1030	1250	1460	112	Hollow Shot.
	10 in.	84	9 4	10.	12	"	350	660	950	1210	1440	1700	82	
		62	8 4	10.	8	"	280	570	820	1030	1250	1460	76	
	8 in.	65	9 0	8. 05	10	5 4	330	630	1000	1225	1515	1700	56	
		60	8 6											
	8 in.	65	9 0	8. 05	10	5 4	400	645	930	1270	1460	1650	48	
		60	8 6											
	8 in.	50	6 8	8. 05	8	12 7	300	530	770	1010	1230	1460	56	
							½°	¾°	1°	1¼°				
	8 in.	50	6 8	8. 05	5	12 7	200	300	400	500			48	

Within the limits of ordinary ranges and estimation of distances, the above table will answer for practice with all the corresponding classes of guns used in the U. S. naval service. A practice table is being constructed under the direction of the Bureau of Ordnance, which, it is presumed, will be published at the proper time. Attention is called to the effect of windage in the 40 cwt. 32-pounder, where a reduction of windage of .06 inch, caused the shot to range equally with the 48 cwt. gun, notwithstanding the charge had been reduced one-fourth.

TABLE II.

Ranges by Ricochet, with Iron Ordnance, single shotted, on board H. B. M. ship Excellent.—Elevated by quadrant.

Nature of the Gun.	Length.	Charge.	Height above plane.	Elevation.	First Graze.	Extreme graze before deflection.	No. of Grazes.		Remarks.
	Ft. In.	lb. oz.	Ft. in.	°					
10 inch,	9 4	12	12 6	¼	280	2850	16	Hollow shot. 84 lbs.	
				1	650	2700	14		
				2	750	2680	18		
8 inch,	9 0 / 8 6	10	12 6	¼	340	2900	32	Hollow shot. 56 lbs.	
				1	626	2766	23		
				2	970	2576	14		
8 inch,	6 8	7	5 4	¼	331	2150	14	Hollow shot. 56 lbs.	The ricochet ranges were generally obtained when the water was perfectly smooth. It has been observed, that a slight ripple diminishes the range considerably.
				1	653	2017	14		
				2	933	2333	9		
32-pdr.	9 7	10	12 6	¼	350	2850	24		
				1	880	2900	15		
				2	1220	2658	12		
32-pdr.	8 0	8	5 4	¼	305	2613	12		
				1	706	2593	14		
				2	1117	1907	8		
32-pdr.	8 0	6	5 6	0	326	2336	19		
				1	700	2100	8		
				2	1026	2410	16		

TABLE III.

Ranges with Iron Ordnance, double shotted, obtained on board H. B. M. ship Excellent.—Elevation by Tangent sight.

Nature of Gun.	Length.	Charge.	Height above plane.	Range in Yards.					Remarks.
				100	200	300	400	500	
	Ft. In.	lbs.	Ft. in.	°	°	°	°	°	
32-pdr.	9 7	6	12 6	¼		1	1¼	1½	
32	8 0	5	12 6	¼	½	¾	1 7/16	1¾	
32	9 0 / 7 6	4	19 6	¼	½	¾	1⅝	2	Shell Guns and Carronades are never to be double shotted.
32	6 6	3	19 4	½	1	1½	2¼	2⅜	
24	9 0	4	19 4	⅓	¾	1⅛	1¼	1½	
18	8 0	3	19 4	⅓	⅞	1¼	1⅜	1⅝	

TABLE IV.

The mean deviations of projectiles by "Experiences à Gavrés."

Gun.	Projectile.	Charge.	Distances Metres. 600	800	1000	1200	1400	1600	1800	2000	2200
Canon de 30 long.	Solid shot.	$5^k.00$	$1^m.0$	$1^m.9$	$3^m.1$	$4^m.7$	$6^m.7$	$9^m.1$	$12^m.0$	$15^m.5$	$19^m.6$
		3 .75	1 .1	2 .0	3 .3	5 .0	7 .1	9 .6	12 .7	17 .4	20 .8
		2. 50	1 .2	2 .2	3 .7	5 .5	7 .8	10 .6	14 .0	18 .1	22 .9
	Hollow shot.	3 .75	1 .5	2 .8	4 .6	7 .1	10 .3	14 .3	19 .3	25 .5	33 .1
		2 .00	1 .6	3 .1	5 .1	7 .8	11 .2	15 .7	21 .2	28 .0	36 .3
Howitzer of $0^m.22$	Solid.	3 .50	0 .7	1 .5	2 .5	3 .7	5 .1	6 .8	9 .1	11 .7	
	Hollow.	3 .50	1 .5	2 .7	4 .4	6 .6	9 .4	12 .9	17 .1	22 .1	28 .1

TABLE V.

Mean lateral deviation of a 30-pounder solid shot (French), fired from a floating platform or pontoon.

Amplitude of rolls.	Amplitude of pitching.	Range Yards.	Deviation. Yards.	No. of rounds.
8°	5°	1453	6.5	20
8°	3°	1686	10.9	20
3°	3°	1931	6.7	20
3°	3°	2230	9.7	20

TABLE VI.

Penetration of projectiles in oak by "Experiences à Gavrés."

Species of Gun.	Projectile.	Charge.	Distances Metres. 1000	1200	1400	1600	1800	2000	2200
Canon de 30 long.	Solid.	$5^k.00$	$0^m.64$	$0^m.54$	$0^m.44$	$0^m.37$	$0^m.30$	$0^m.25$	$0^m.21$
Howitzer of 0^m 22	Hollow.	3 .50	0 .42	0 .34	0 .28	0 .22	0 .18	0 .14	0 .11

For all practical purposes the Canon de 30 and Howitzer of $0^m.22$ may be considered equivalent to the 32-pounder gun and 8 inch shell gun. To reduce metres to yards, cut off the last figure and multiply by 11. To reduce yards to metres, multiply by 9 and cut off the last figure; the result will be accurate within $\frac{6}{10}$ of one per cent. To reduce the penetrations to inches, divide by 0.0254. The kilogramme is equal to 2.2 lbs., nearly.

TABLE VII.

Initial velocity of double shot and dispersion.

Canon de 30 long.—Charge 3k.75.		
Distance in metres.	Initial velocity of ball.	
	In contact with cartridge.	Furthest from cartridge.
	286m	364m
	Dispersion	
	Horizontal.	Vertical.
50m	0m.31	0m.21
100	0 .59	0 .49
150	0 .63	1 .23
200	0 .95	1 .38
250	0 .72	2 .82
300	1 .44	2 .86
350	1 .61	3 .36
400	2 .03	4 .19

TABLE VIII.

Spread of grape of 15 balls, calibre de 30.		
Distance.	Without shot.	Shot in contact with cartridge.
100m	3m.04	2m.57
200	6 .08	5 .14
300	9 .12	7 .71
400	12 .16	10 .28

STAATSBIBLIOTHEK BAMBERG

Chambers.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.



Fig. 5.

Fig. 6.

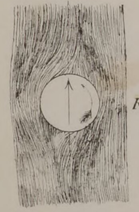




Fig. 7.

Fig. 8.

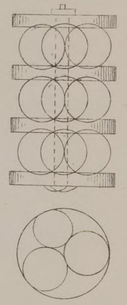


Fig. 9.

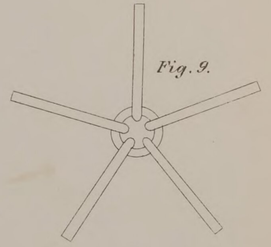
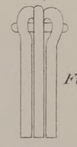


Fig. 9. (bis.)



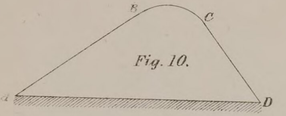


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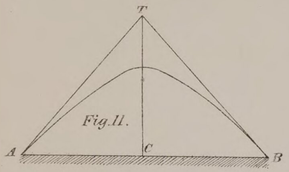


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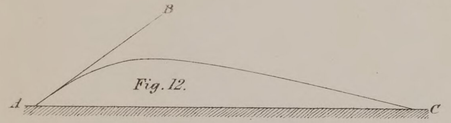


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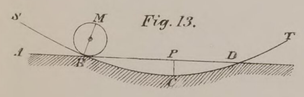


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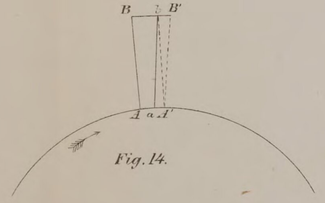


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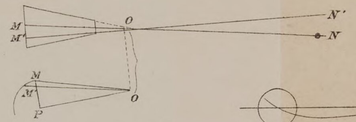


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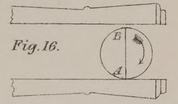


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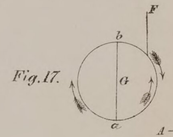


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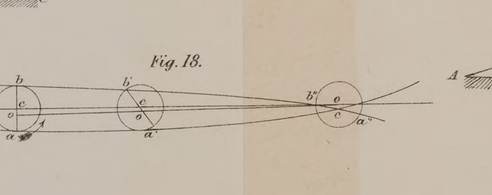


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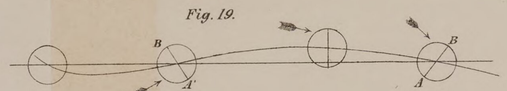


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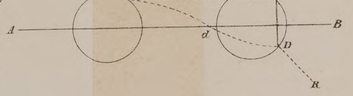


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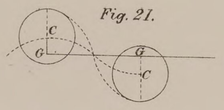


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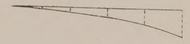


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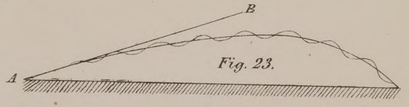


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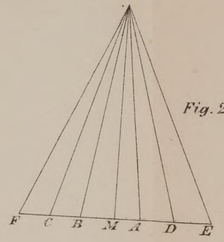


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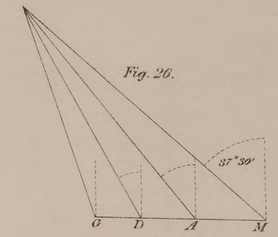


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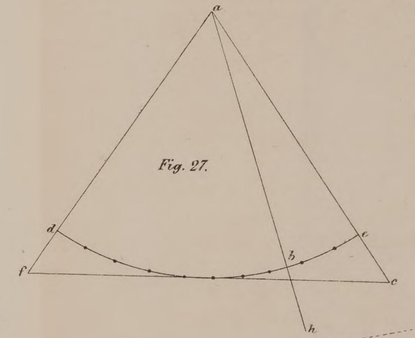
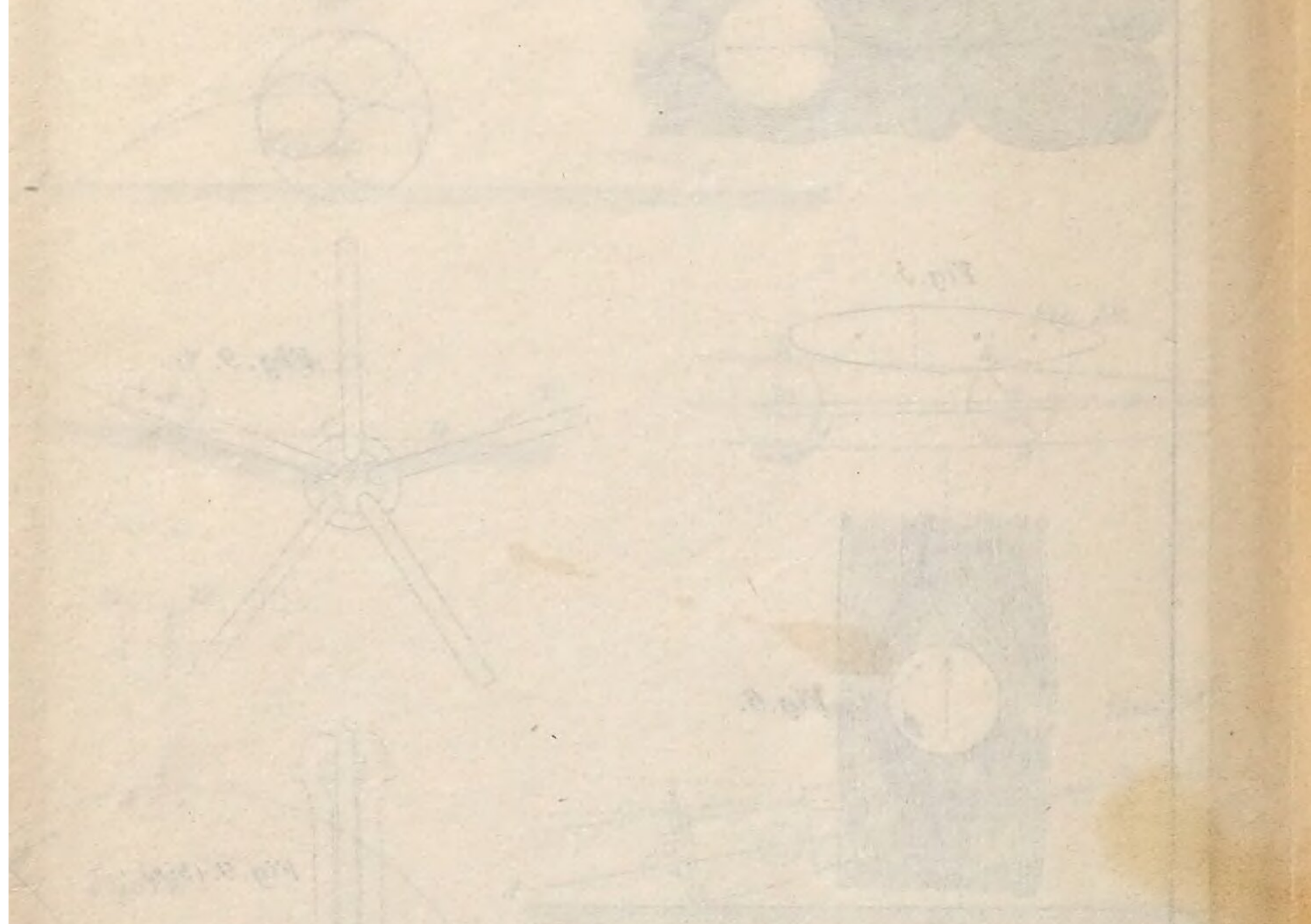


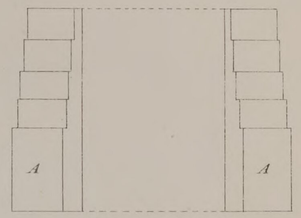
Fig. 27.

Fig. 24.

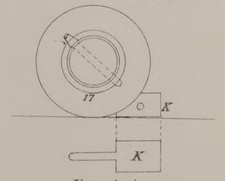
Lith. of W. Endicott & Co. N.Y.



8 IN. SHELLGUN OF 63 CWT. AND CARRIAGE, NEW PATTERN.



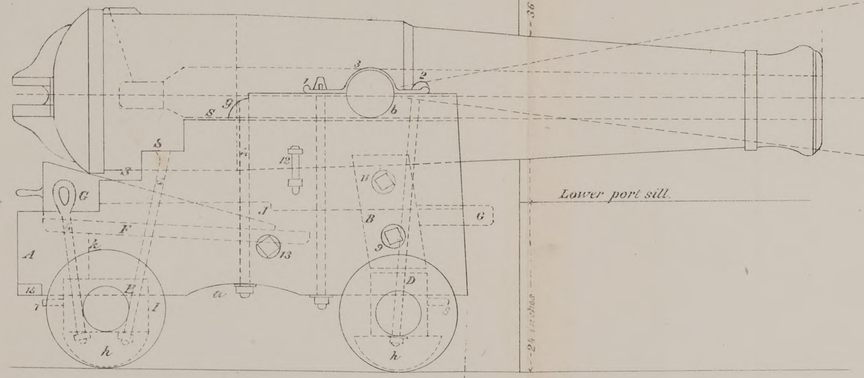
End view of Cheeks.



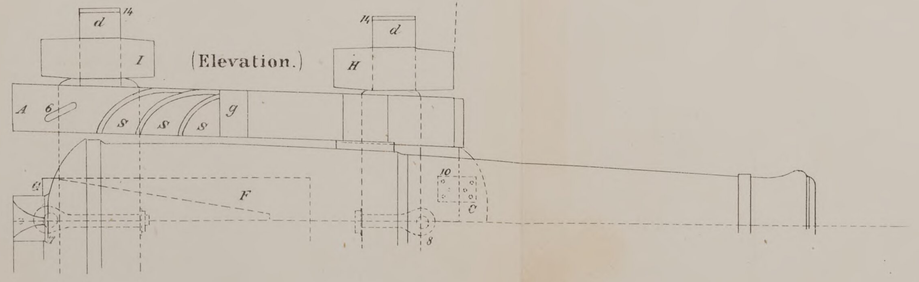
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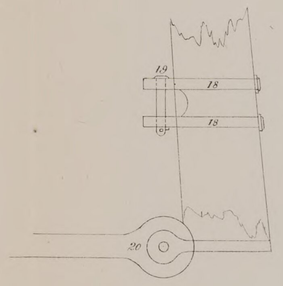
Front view.

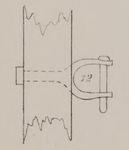
(Elevation.)



(Elevation.)





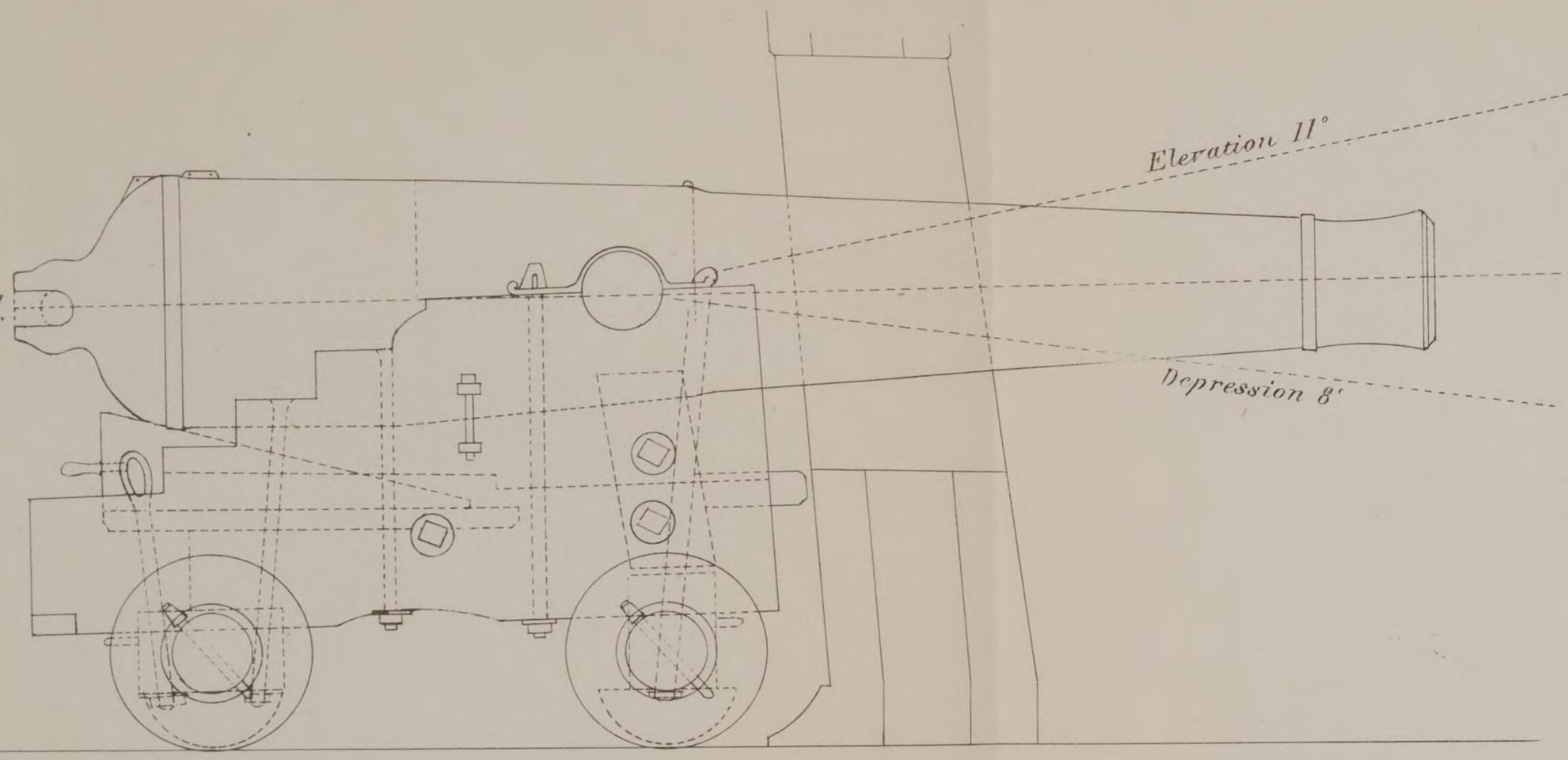


Scale 20

Lith. of Wm. Endicott & Co. N. Y.

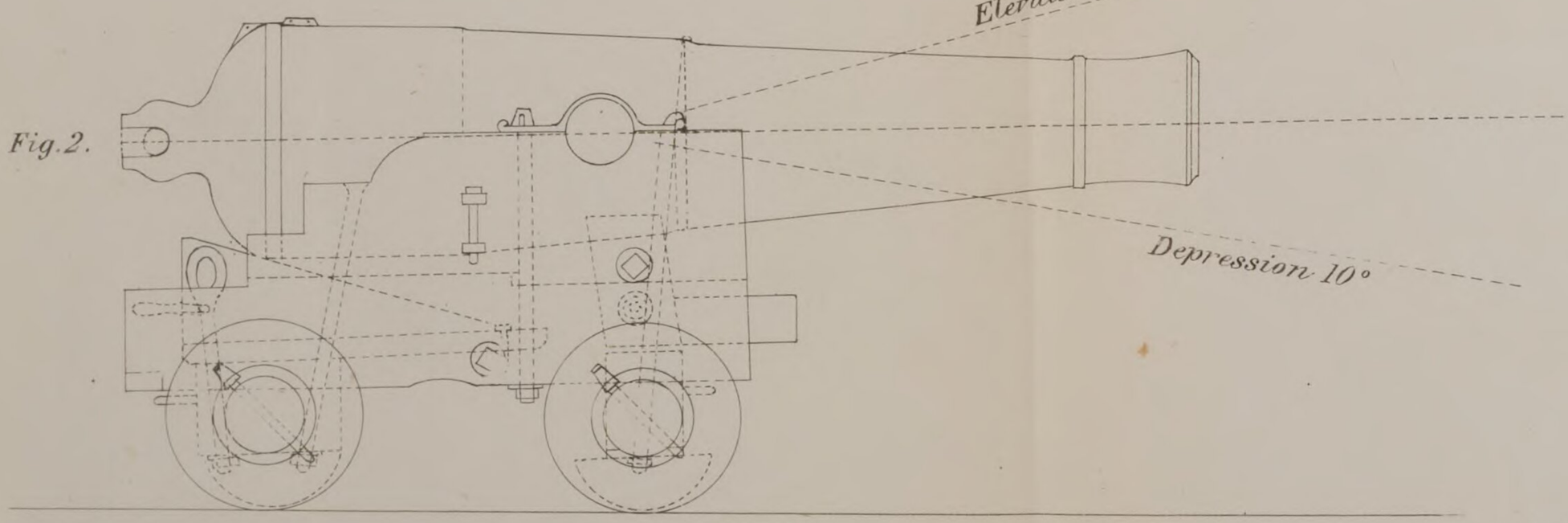
32 PDR GUN OF 51 CWT, AND CARRIAGE _ NEW PATTERN.

Fig. 1.



32 PDR GUN OF 32 CWT AND CARRAGE NEW PATTERN.

Fig. 2.



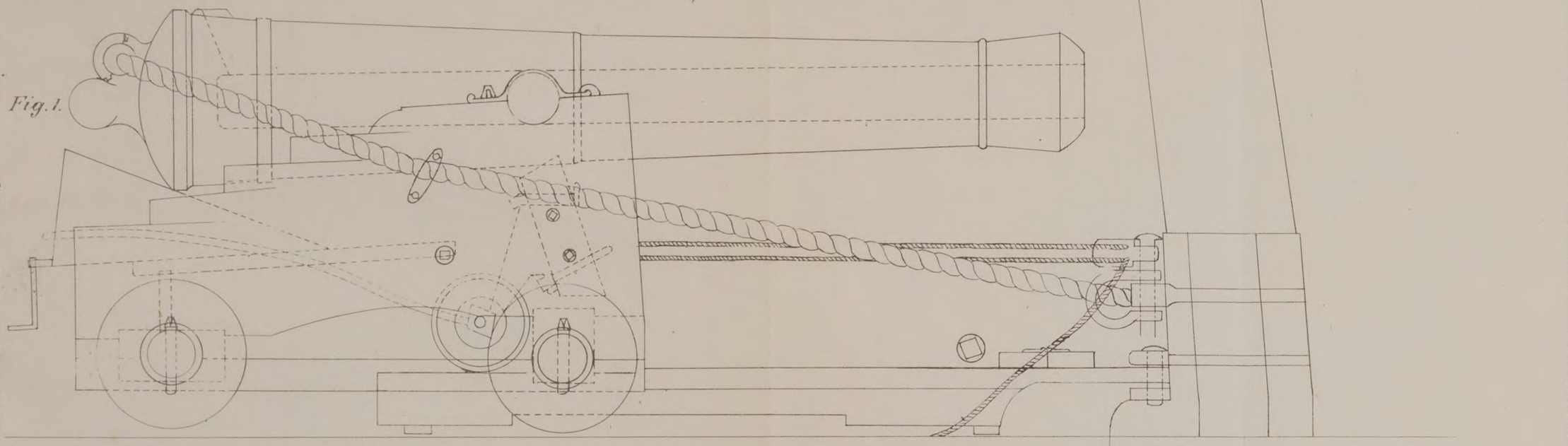
Scale $\frac{1}{20}$

Lith. of W. Endicott & C. N.Y.

Lt. WARD'S CARRIAGE FOR 32 PDR GUN OF 61 CWT. OLD PATTERN.

(Elevation.)

Fig. 1.



(Plan.)

Fig. 1./bis.

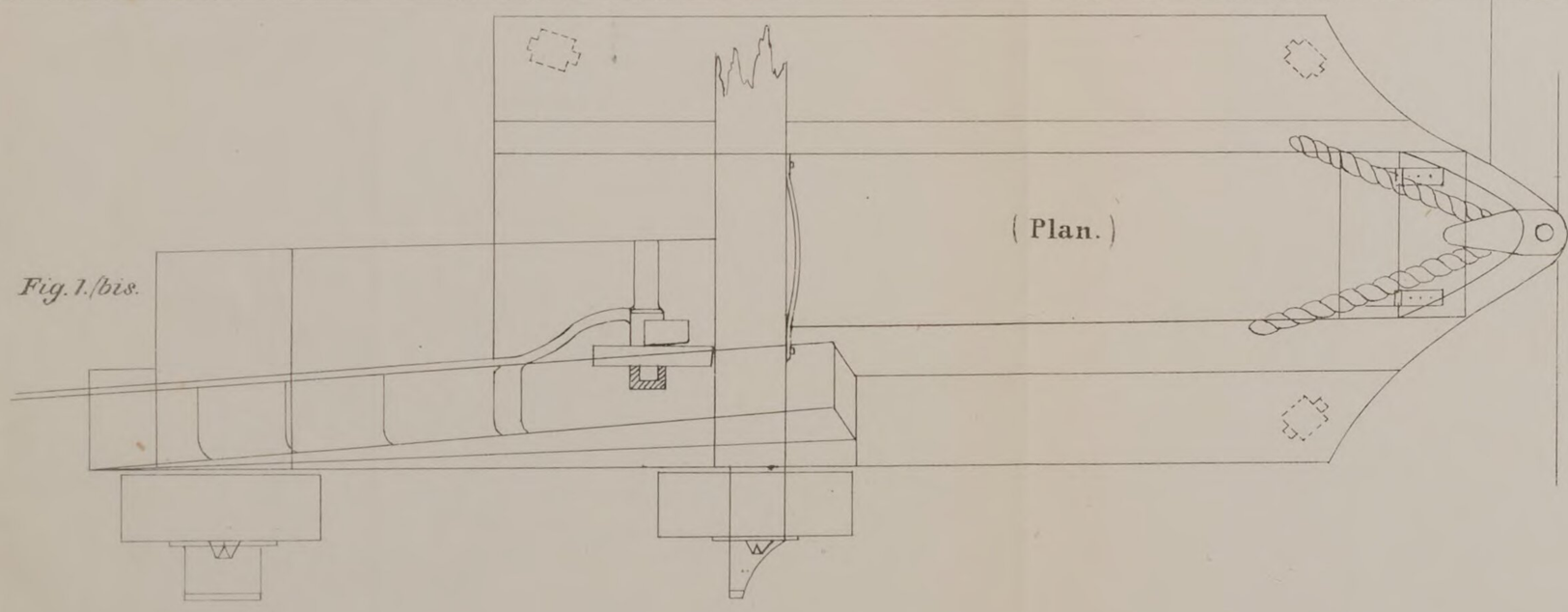
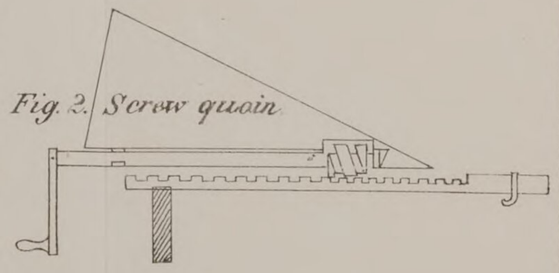


Fig. 2. Screw quoin



Scale 1/20.

Lith. of Wm. Endicott & Co. N.Y.

ROMME CARRIAGE,

(for 30 pounder bomb cannon.)

Fig. 1. (elevation.)

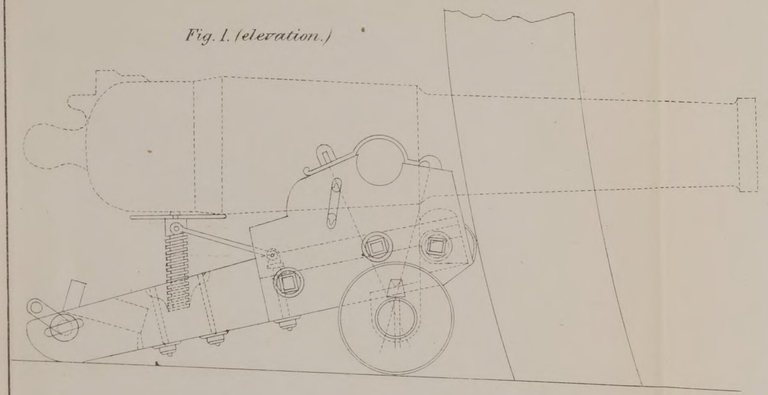


Fig. 1. (plan.)

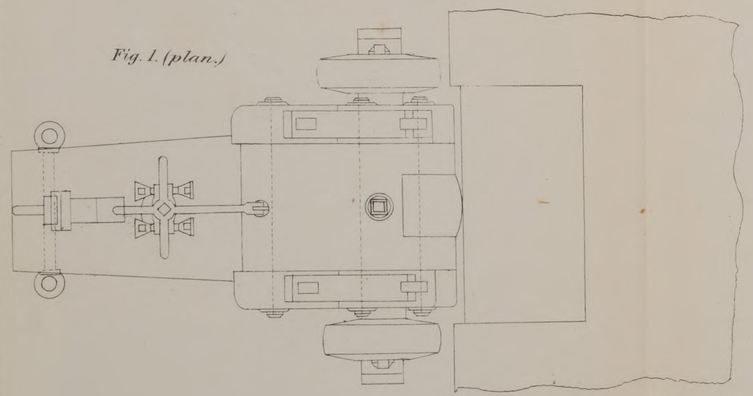
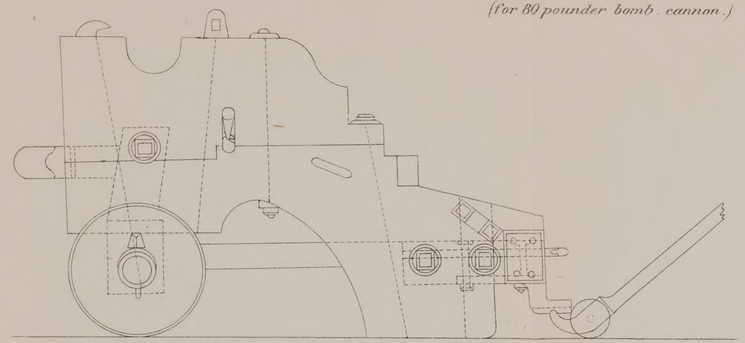


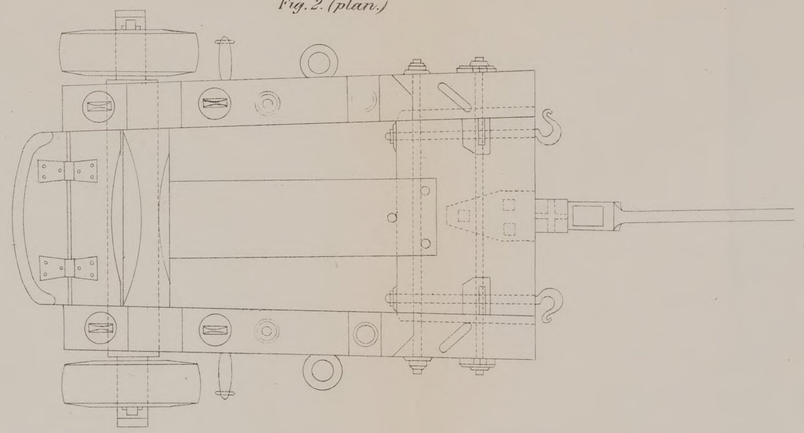
Fig. 2. (elevation.)



MARSILLY CARRIAGE,

(for 80 pounder bomb cannon.)

Fig. 2. (plan.)



ROMME CARRIAGE,

(for 80 pounder bomb cannon, with compound screeching, at extreme recoil.)

Fig. 3.

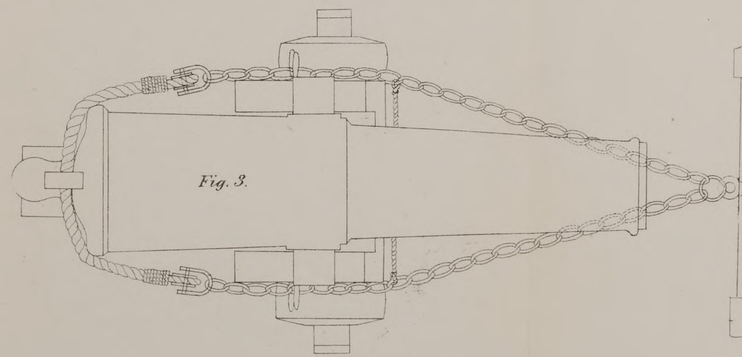


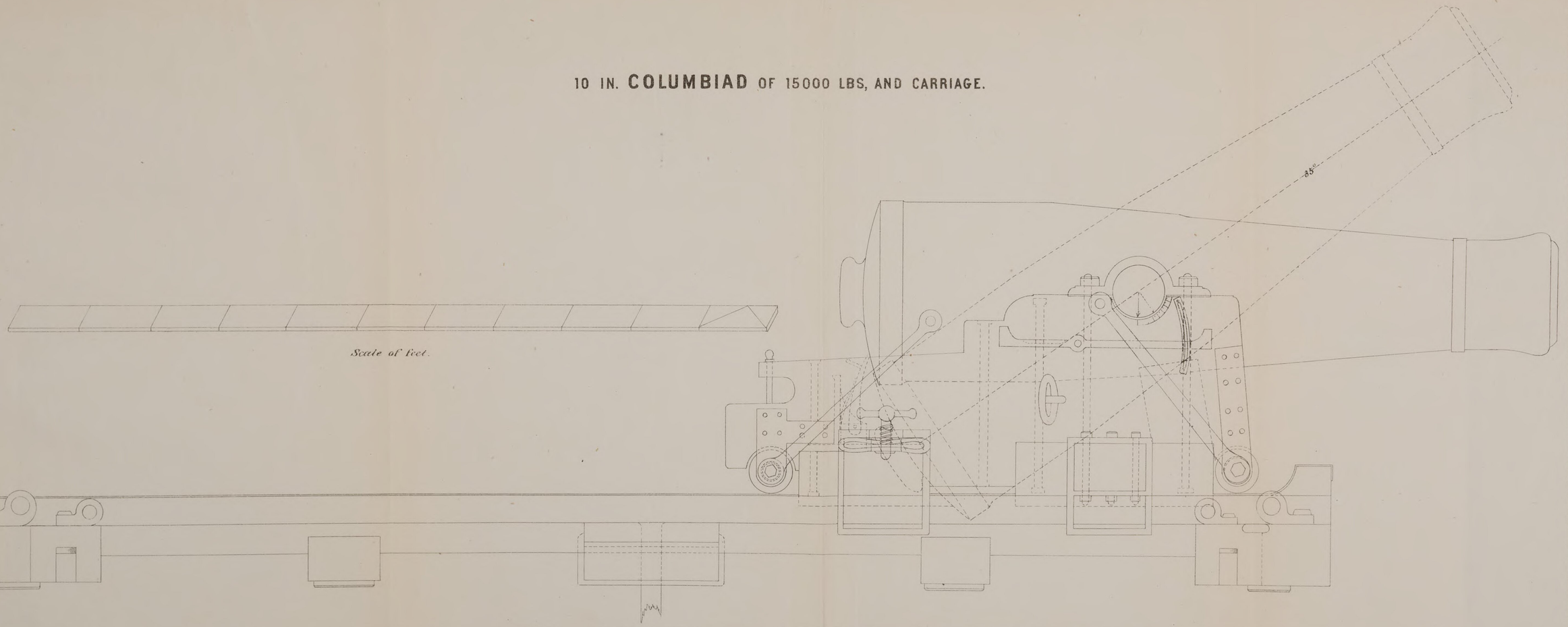
Fig. 4.

ROLLER HANDSPIKE.



Lith. of Wm. Endicott & Co. N. Y.

10 IN. COLUMBIAD OF 15000 LBS, AND CARRIAGE.



Lith. of Wm Endicott & Co N.Y.

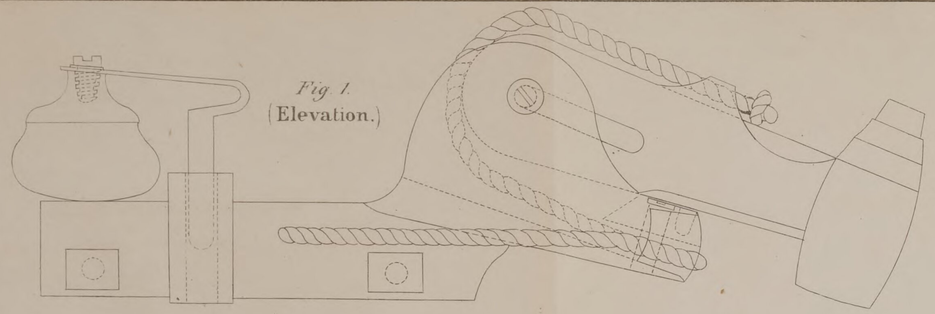


Fig. 1.
(Elevation.)

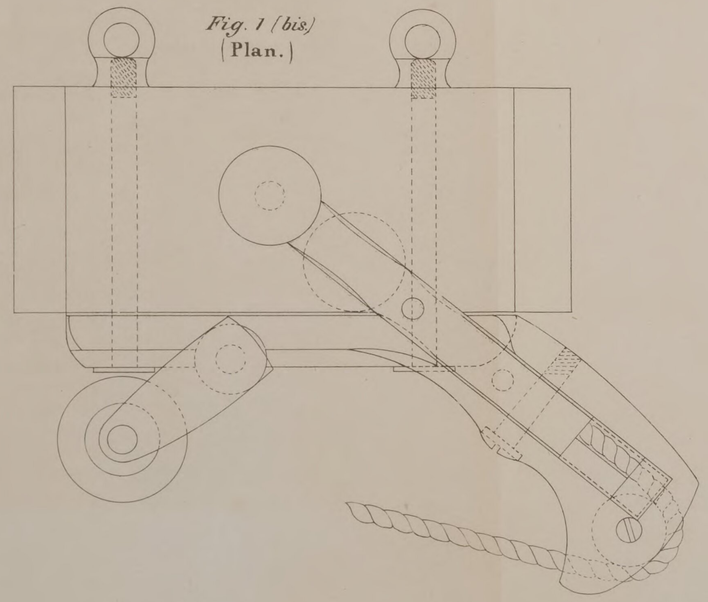


Fig. 1 (bis.)
(Plan.)

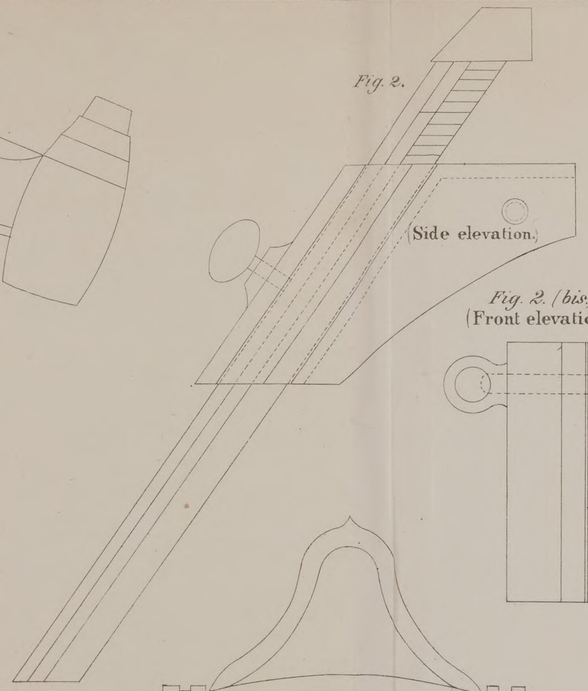


Fig. 2.
(Side elevation.)

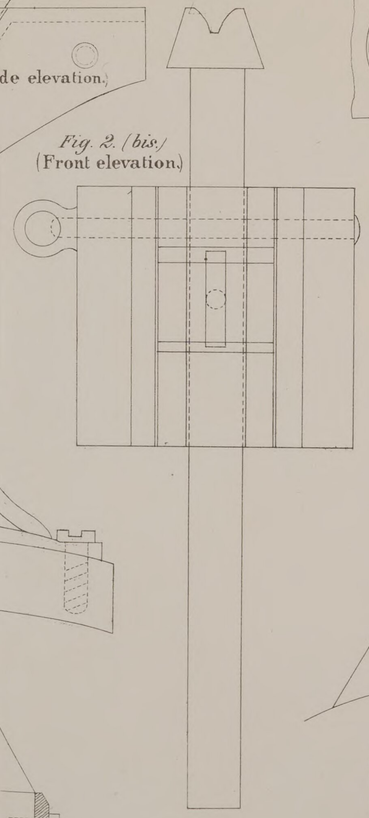


Fig. 2. (bis.)
(Front elevation.)

Fig. 3. (Elevation.)

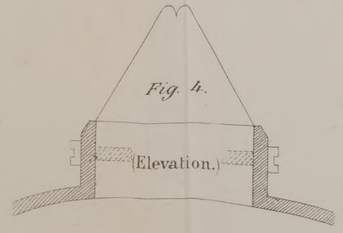


Fig. 4.
(Elevation.)

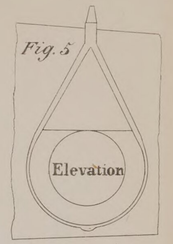


Fig. 5
Elevation

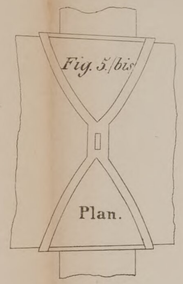


Fig. 5. (bis.)
Plan.

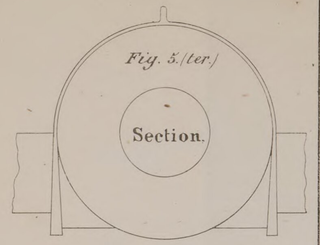


Fig. 5. (ter.)
Section.

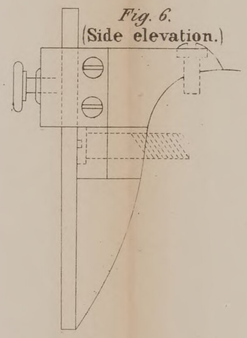


Fig. 6.
(Side elevation.)

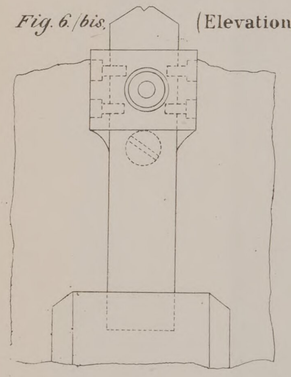


Fig. 6. (bis.)
(Elevation.)

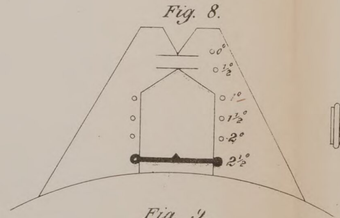


Fig. 8.

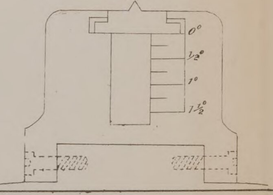


Fig. 9.

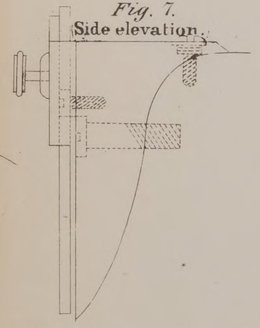


Fig. 7.
Side elevation.

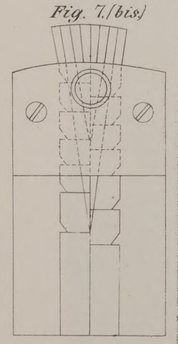


Fig. 7. (bis.)

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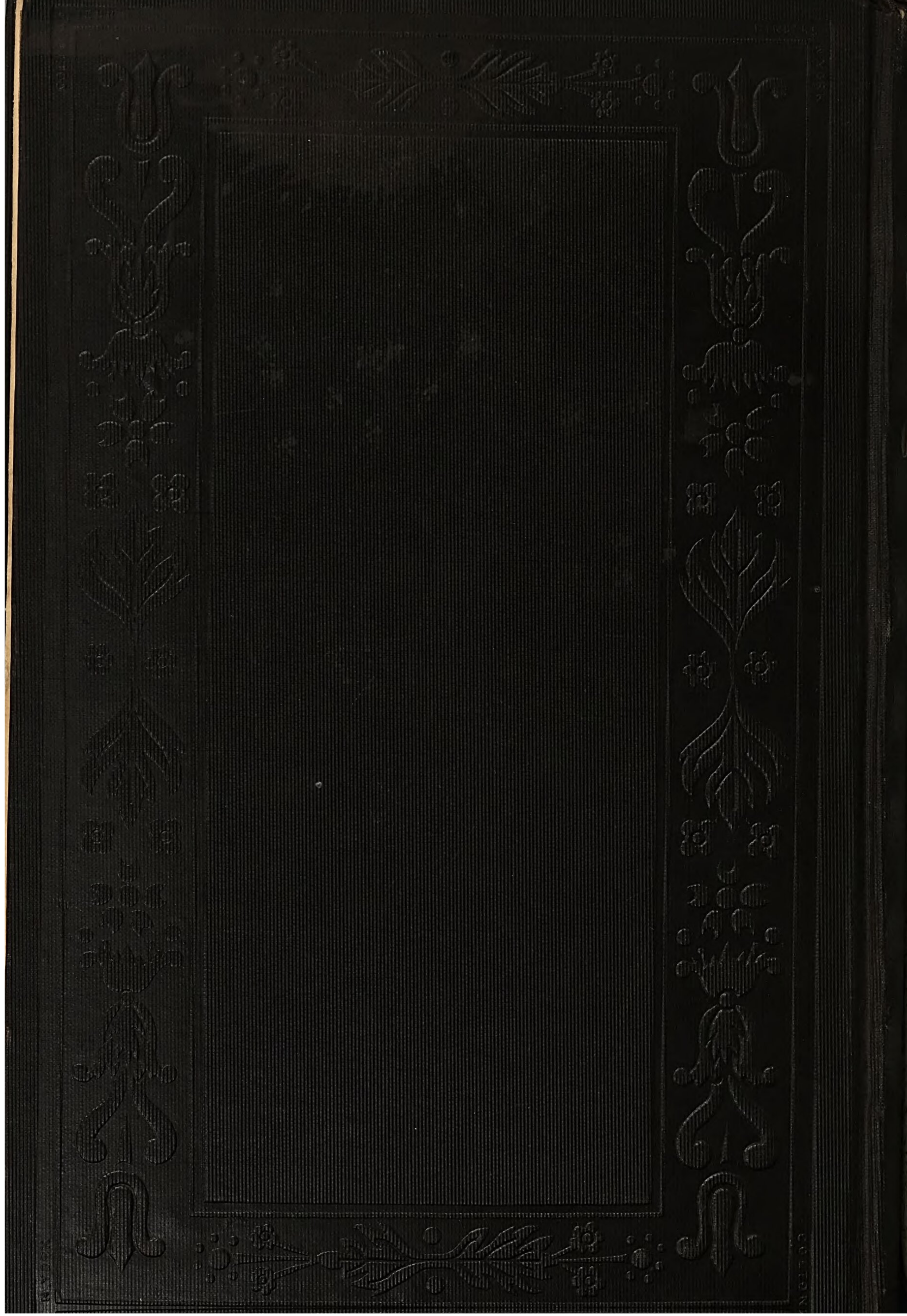
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